

ESSAY ON VISION

GEORGE ADAMS
LONDON, ENGLAND
1792

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AN
ESSAY
ON
VISION,
BRIEFLY EXPLAINING THE
FABRIC OF THE EYE,
AND THE
NATURE of VISION:

INTENDED FOR THE SERVICE OF THOSE WHOSE
EYES ARE WEAK OR IMPAIRED:

ENABLING THEM TO FORM AN ACCURATE IDEA OF
THE TRUE STATE OF THEIR SIGHT, THE MEANS
OF PRESERVING IT, TOGETHER WITH PROPER
RULES FOR ASCERTAINING WHEN SPECTACLES ARE
NECESSARY, AND HOW TO CHOOSE THEM WITHOUT
INJURING THE SIGHT.

By GEORGE ADAMS

Mathematical Instrument Maker to His Majesty, and Optician to
His Royal Highness the Prince of Wales

THE SECOND EDITION.

L O N D O N :

Printed for the AUTHOR, by R. HINDMARSH,

PRINTER TO HIS ROYAL HIGHNESS THE PRINCE OF WALES,
No. 32, Clerkenwell-Close :

And Sold by the Author, at his Shop, No. 60, FLEET-STREET.

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1792.
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P R E F A C E .

THE following Essay is so short, that there is no occasion for a long preface to introduce it to the readers' notice. One of the principal ends of it is to do away a general prejudice in favour of spectacles, namely, that they act as preservers; a prejudice which has caused numbers to use glasses, before they could be of any essential service; who thereby force their eyes into an unnatural state, and bring on a very unpleasant habit. To remedy this evil, the marks are distinctly pointed out, which determine when the use of glasses will be serviceable to the eye. By an attention to the rules here laid down, they will be taught neither to anticipate evil, by a premature use of spectacles; nor, by too long a delay, to strain and injure their sight.

A second end was, to diffuse more generally a knowledge of the subject among the venders of this article, particularly those who live in the country; and this was the more necessary, as numerous instances are continually occurring to every optician, of those whose sight has been injured by an improper choice of spectacles.

The nature of the Essay has given me an opportunity of pointing out rules for the preservation of the sight, and avoiding what may be hurtful to it. Among the latter, the two principal articles are, the use of reading-glasses, and opaque shades to candles; both of which I have reason to think, are extremely prejudicial to the eyes.

As this Essay may probably fall into the hands of those who may have no opportunity of consulting more scientific works I have concluded it with an account of squinting, the proper methods of ascertaining the nature of it, and the best known remedies for it.

I have here to notice an error, into which, in common with most late anatomists, I have fallen, with respect to the structure of the iris, and the situation of the crystalline. Mr. O'Halloran asserts, that the iris is not flat, but very convex, and that the inside of the iris adheres closely to the anterior part of the vitreous humour, except where it opens for the lodgment of the crystalline, and consequently that there is no posterior chamber for the aqueous humour. For a fuller account, I must refer the reader to the author's paper.*

* Transactions of the Royal Irish Academy for the year 1788.

I take this opportunity of thanking my friends for several valuable remarks and corrections, but particularly W. C. Wells, M.D. author of "an Essay on single vision with two eyes," printed for Cadell; a Treatise which every one should read, who is desirous of seeing that difficult subject put in a clear light.

I have subjoined a list of the authors, to whom I am indebted for my information on the subjects of this Essay.

Ayscough.	Short Account of the Eye.	London, 1757
Chandler.	Treatise on the Diseases of the Eye.	London, 1780
De la Caille.	Leçons Elementaire d'Optique.	Paris, 1766
	The Fabric of the Eye.	London, 1758
Harris.	Treatise of Optics.	London, 1775
Haller.	First Lines of Physiology.	Edinburgh, 1786
Le Cat.	Physical Essay on the Senses.	London, 1750
Martin.	Essay on Visual Glasses.	London, 1756
Nicholson.	Introduction to Natural Philosophy.	London, 1787
Porterfield.	Treatise on the Eye, 2 vols. 8vo.	Edinburgh, 1759
Priestley.	History and present State of Discoveries relating to Vision.	London, 1772
Reid.	Inquiry into the Human Mind.	London, 1785
Smith.	Compleat Treatise of Optics.	Cambridge, 1738
Thomin.	Traité d'Optique.	Paris, 1749
Trabaud.	Le Mouvement de la Lumière.	Paris, 1753
Warner.	Description of the Human Eye.	London, 1773

AN
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VISION.

IT is proposed in this essay to instruct those whose eyes are beginning to fail, how to form a right judgment of the state of their sight, and of the means of preserving it; how to determine when the use of spectacles is necessary, and so to use them, that the sight may neither be injured by a premature application of glasses, nor strained for want of proper assistance.

But in order to enable the reader to judge for himself, and know how to chuse his spectacles, when a choice becomes necessary, it will be proper first to explain the structure of the eye, and the means by which vision is performed: for by understanding the principles on which the operations of this wonderful organ depend, he will learn how it may be impaired, and by what assisted. It is also presumed, that it can be no unpleasing speculation to obtain an idea of the secret mechanism by which the eye communicates so many diversified and animated perceptions to the soul, and by which we are enabled to discover, with so much ease and rapidity, every surrounding object.

In the structure of the eye we find the most evident manifestations of exquisite art and design, every part elegantly framed, nicely adjusted, and commodiously placed, to answer in the most perfect manner every possible good purpose, and thus evince that it is the work of unerring wisdom, prompted to action by infinite love.

So manifold are the blessings we derive from this organ, that the mind of man seems almost inadequate to the conception, and his pen to the description of them. While it forms our ideas of magnitude and distance, it annihilates space, by placing the nearest and most distant objects close together. To it we are indebted for the delightful sensations that arise from the proportion and variety of forms, the harmonious mixture of colours, and the graces of beauty. It enables us to seek, to see, and to

chuse our food ; to go here and there, as the calls of friendship, or the occasions of business, require ; to traverse the ocean, ransack the bowels of the earth, visit distant regions, accumulate wealth, and multiply knowledge. Assisted by it, we become acquainted with the works of the Creator, and can trace his wisdom, his power, and his goodness, in the texture of plants, the mechanism of animals, and the glories of the heavens.

The value of this sense is heightened, when we consider the miseries attendant on the want of it ; for among the numerous evils that afflict the human race, there is none more justly dreaded, nor more deeply deplored, than a deprivation of sight. It is to have one of the chief inlets of happiness cut off, to be shut up in perpetual darkness, to labour under ten thousand inconveniences, and to be exposed to continual dangers. How poignantly this loss was felt by our great poet, is painfully evident from his own words :

“With the year
Seasons return ; but not to me returns
Day, or the sweet approach of ev’n or morn,
Or sight of vernal bloom, or summer’s rose,
Or flocks, or herds, or human face divine ;
But cloud instead, and ever-during dark
Surrounds me, from the chearful rays of men
Cut off, and for the book of knowledge fair,
Presented with an universal blank
Of nature’s works, to me expung’d and raz’d,
And wisdom at one entrance quite shut out.”

A short Description of the Eye.

In describing the eye, it is natural to consider, first, the external parts, then the internal, or those which are more immediately subservient to the purposes of vision.

The eye, as is well known, is situated below the forehead ; it is placed in a bony cavity, called the *orbit* ; the form is globular, it is composed of several coats and humours, and furnished with vessels properly adapted to it’s various functions.

The eye consists of several *coats* or teguments, which form a *ball* perfectly globular except on the fore part, which is a little more protuberant than the rest. Within this ball are included three different liquids or transparent substances, called humours.

The *orbit* of the eye is of a conical shape, but rather irregular in it's dimensions; it is composed of seven bones, and lined with fat, which forms a soft bed for the eye to rest on, and facilitates it's various motions. A considerable part of the bottom of the orbit is open for the admission and transmission of the nerves, veins, and arteries.

Those prominent arches of hair, which we term the *eyebrows*, defend the eyes from the light when it is too strong, and prevent their being incommoded by any substances that might slide down the forehead, and thence fall into the eyes. That the eyebrows may be more effectually useful, and form a more perfect screen, they are furnished with muscles to draw them down, and corrugate them; and when we are walking in a dusty road, or when we are exposed to a dazzling light, we pull down the eyebrows, and thereby shade the eye from the glare, and protect it from the dust. We may gather from hence, that those shades which encompass the forehead, and that project about three inches from it, are properly adapted to guard weak eyes from every offensive glare of light.

The prominency of the eyebrows gives a character to the face; and hence Le Brun, in his directions to a painter, with regard to the passions, places in them the principal force of expression. The eyebrows form a deep shade on the canvas, which relieves the other colours and features. A depression of the eyebrow is an indication of concern and grief; whilst an elevation thereof shews that the mind is either affected with joy, or enjoying the serene delights of tranquility.

The *eyelids*, like two substantial curtains, protect and cover the eyes while we sleep; when we are awake, they diffuse, by their motion, a fluid over the eye, which cleans and polishes it, and thus renders it fitter for transmitting the rays of light.

Each eye is furnished with two lids, the one superior, the other inferior, joining at the two extremities, which are called *canthi*, or angles. Both eyelids are lined with a membrane, which also infolds as much of the globe

of the eye as is called the white, and it prevents any dust, or other extraneous particles, from getting behind the eye into the orbit.

That the eyelids may shut with greater exactness, and not fall into wrinkles when they are elevated or depressed, each edge is stiffened by a cartilaginous arch. The eyelashes, like two palisades of short hair, proceed from these cartilaginous edges, warning the eye of danger, protecting it from straggling motes, and warding off the wandering fly. They also intercept many rays proceeding from objects that are above the axis of vision, and thereby render the images of other objects more distinct and lively: for, as in the camera obscura, the image is always brightest when no rays are allowed to enter, but those which form the picture. The eyelashes contribute their share in giving beauty to the face, to soften the outlines of the eyelids, and throw a mildness on the features.

Both the eyelids are moveable; but the upper one mostly so, the lower one moving but little, being rather obsequious to the motions of the adjacent parts, than moved by any particular forces of it's own. The hairs of the eyelashes grow only to a certain length, and never need cutting: the points of the superior one are bent upwards, those of the lower eyelash downwards. Thus whenever we can trace things to their final cause, we find them always marked with design, and can find no circumstance so minute, as to escape the attention of the Supreme Being.

From what has been said, we may perceive why the sight of those, whose eyelashes are black, is, in general, much stronger than those who have them fair or white; the black eyelashes are a better shade for the eye, and reflect no light from their inner side, to weaken and efface the picture of the retina. *Montaltus* gives an account of a young man, whose eyelashes and eyebrows were of an intense white, and his sight obscure during the day, but clear at night. This person was taken prisoner by the Moors, who dyed his eyelashes black, by which his sight was much strengthened; in course of time the dye was washed off, and the sight became weak again. Dr. Russell, in his natural history of Aleppo, says, that it is the custom among the Turkish women to black the inside of their eyelids, not only as an ornament, but as a means of strengthening the sight. When the eyelashes are lost, a symptom which frequently follows a malignant small-pox, the sight is always considerably impaired.

By shutting the eyelids partially, we can exclude as much light as we please, and thus further defend the eyes from too strong a light, which every one's experience proves to be as injurious to them, as more gross matter. Numerous are the melancholy instances on record, which confirm this truth: Xenophon relates, that many of his troops were blinded by the strong reflection of light from the snow over which they were obliged to march. Dionysius, the tyrant of Sicily, among other means which he used to gratify his revenge, and satiate the cruelty of his temper, was accustomed to bring forth his miserable captives from the deep recesses of the darkest dungeons, into white and well-lighted rooms, that he might blind them by the sudden transition from one extreme to the other. Actuated by principles equally cruel, the Carthaginians cut off the eyelids of Regulus, and then exposed him to the bright rays of the sun, by which he was very soon blinded.

These facts make it clear that a protuberant eye is not so well constituted for vision, as one that is deep sunk in the head: neither extreme is indeed desirable, yet undoubtedly, of the two, that which is deep set is preferable, as affording the clearest sight, and being least liable to injuries from external accidents.

Those animals which have hard crustaceous eyes, as the lobster, crab, &c. have no eyelids; whereas most brute animals have an additional one, called the *nictitating membrane*, which they draw over their eyes like a curtain, to wipe off whatever incommodes them.

The velocity with which the eyelids move to and fro is so great, that it does not in the least impede the sight. This curious circumstance may be illustrated by the well-known phenomenon of a burning coal appearing like a ring of fire, when whirled round about with rapidity, in the circumference of a circle. Now it is highly probable, that the sensation of the coal, in the several places of the circle, remains on the mind until it returns again to the same place. If, therefore, our eyelids take no longer time to pass and repass upon our eyes, than what the coal of fire takes to go round, the impression made by any object on the eye will suffer no sensible interruption from this motion.

To prevent the eyelids adhering together, they are supplied with a row of sebaceous glandules, which discharge a soft liniment, that mixes with, and is washed off with the tears.

The *lachrymal gland* is placed in the upper and outer part of the orbit. It is designed to furnish at all times water enough to keep the outer surface of the eye moist, and thus give the cornea a greater degree of pellucidity. In order that this liquor may be rightly disposed of, we frequently close the eyelids without being conscious of it.

At the inner corner of the eye, between the eyelids, stands a caruncle, whose office seems to be to keep that corner of the eye from being totally closed; so that any tears, &c. may flow from under the eyelids when we sleep, into the *puncta lachrymalia*, which are little holes, one in each eyelid, near the corner, for carrying into the nose any superfluous tears.

The eye is furnished with six muscles, which spread their tendons far over the eye; by these it can be moved upwards and downwards to either side, and in every intermediate direction, and thus view surrounding objects without moving the head. To facilitate these motions, a great quantity of loose fat is placed all round the globe of the eye, between it and the orbit. Four of the muscles are strait, and two oblique; of the strait muscles, two are situated vertically opposite one another, and the other two horizontally. Each of the six has a proper name, according to its situation and office. I cannot pass over the muscles, without taking notice of a striking instance of design in the wise disposition of the parts. It is sometimes necessary to have an oblique motion of the eye, towards the nose, and there being no room on that side for muscles, a small bone is placed on the side of the nose, with a hole in it, to serve as a pulley, through which the tendon of a muscle passes to a convenient insertion, and thereby such an oblique motion is given to the eye, as would otherwise have been impossible.

The eyes are placed in the most eminent part of the body, near the brain, the seat of sensation. From their elevated situation, our prospect is enlarged, and the number of objects, taken in at one view, increased; we command an ample horizon on earth, and a glorious hemisphere of the heavens.

Every part of the human frame affords indisputable proofs of the wisdom and beneficence of it's Creator, because all are adapted to answer in the best manner the end for which they were formed. Thus the globular figure of the eye is the most commodious that we can form any idea of, the best adapted for facilitating the various motions of the eye, for containing the humours within, and receiving the images from without.

Many are the advantages that are derived from our having two eyes, some that are known, others that are unknown; for the correspondence of the double parts in the human frame, and their relation to the two great faculties of the human mind, has not been sufficiently attended to by anatomists. By having two eyes, the sight is rendered stronger, and the vision more perfect; for as each eye looks upon the same object, a more forcible impression is made, and a livelier conception formed by the mind.

The eyes together view an object in a different situation from what either of them apart would do, and enable us to perceive small distances accurately. Hence we find, that those who have lost the sight of one eye, are apt to make mistakes in the distances of objects, even within arm's length, that are easily avoided by those who see with both eyes. Such mistakes are principally seen in snuffing a candle, threading a needle, or in filling a tea-cup. This aptness to misjudge distances and situations is, however, gradually diminished by time and practice.

When an object is placed at a moderate distance, we see more of it by means of the two eyes, than we possibly could with one; the right eye seeing more of the right side, and the left eye more of it's corresponding side. Thus by both eyes we see in some measure round an object: and it is this which assists in giving that bold relief, which we see in nature, and which no painting, how exquisite soever, can attain to. The painter must be contented with shading on a flat surface; but the eyes, in observing natural objects, perceive not only the shading, but a part of the figure that lies behind those very shadings. The perception we have of distance with one eye, as was just now observed, is more uncertain, and more liable to deception than that which we have by both; therefore, if the shading and relief be executed in the best manner, the picture may have almost the same appearance to one eye as the objects themselves would have, but it cannot

have the same appearance to both. This is not the fault of the artist, but an imperfection in the art. To remove these defects, the connoisseurs in painting look at a picture with one eye through a tube, which excludes the view of all other objects. If the aperture in the tube next the eye be small, we have no means left to judge of the distance but the light and colour, which are in the painter's power.*

An object seen with both eyes, appears a little brighter, or more luminous, than it does when seen with one alone, as will be evident by looking alternately with both eyes and with one only: and the difference of brightness will be still more manifest, if at the same time that a part of a flat object, of an uniform colour, is seen with both eyes, the light from the adjacent part is excluded from one of them; which may be done, by applying a book to one side of the head, so that it may reach a little forwarder than the face. But although the difference of brightness, in the two cases, is very perceptible, yet it is not very considerable, nor is it easy to determine it accurately. Dr. Jurin, by a variety of experiments, concluded, that an object seen with both his eyes, appeared only one thirteenth part brighter, than when seen with one alone.

Our eyes have an uniform or parallel motion, by which, when one is turned to the right or left, upwards or downwards, or strait forwards, the other always goes along with it in the same direction. When both eyes are open, we find them always turned the same way, as if both were acted upon by the same motive force. This phenomenon is the more singular, as the muscles which move the two eyes, and the nerves which serve the muscles, are entirely distinct and unconnected.

To account for and explain the cause of this motion, has puzzled the philosopher, and embarrassed the anatomist: that it originates from the grand moving principle, or generating cause within us, the mind, there can be little doubt; but how the mind operates, to produce this effect, we are altogether ignorant. Some effectual purposes are no doubt answered by this motion, for nothing is created in vain. One is supposed to be that of seeing objects single that are viewed with both eyes; for there are two pictures formed of every object, one in each eye. Hence, if any of the muscles of one eye, either from spasm, paralysis, or any other cause, is restrained from following the motion of the other, every object will be seen

* Reid's Inquiry into the Human Mind.

double. The same effect is produced, if while we are looking at any object, we alter the direction of one of our eyes, by pressing it aside with the finger; an experiment frequently made by children, who are generally delighted with any uncommon appearance.

Whatever may be the cause, the fact is certain, that the object is not multiplied as well as the organ, and appears but one, though seen with two eyes: another instance of the skill of the contriver of this noble organ, and the exquisite art he employed in the formation of it.

Having considered the principal external parts of the eye, and shewn that they are framed to protect this delicate organ, with a care strictly proportioned to it's curious texture and extensive usefulness, that it is fortified with strong bones, lodged in a deep receptacle, and guarded with a moveable cover; we now proceed to treat of the internal parts, or those which constitute the globe of the eye.

Of the Globe of the Eye.

"If the construction of the universe were not so evident a proof of the existence of a supremely wise and benevolent Creator, as to render particular arguments unnecessary, the structure of the eye might be offered as one, by no means the least; this instance, among numberless others, demonstrating that the best performances of art are infinitely short of those which are continually produced by the DIVINE MECHANIC.

The globe of the eye, or the organ of sight, may be defined in general as a kind of case, consisting of several coats, containing three pellucid humours, which are so adjusted, that the rays proceeding from luminous objects, and admitted at a hole in the fore part of the eye, are brought to a focus upon the back part of it, where they fall upon a soft pulpy substance, from whence the mind receives it's intelligence of visible objects.

It is not to be expected, that any account given of the eye can be altogether accurate: for as it is impossible to examine all the parts of the eye whilst in a natural and living state, so it is also nearly impossible, when it is taken out of it's socket, to preserve the figure of the parts entire; a circumstance which accounts for the disagreement we find among anatomists.

Of the Coats of the Eye.

The eye is composed externally of three coats or teguments, one covering the other, and forming a ball perfectly globular, except at the fore part, which is a little more protuberant than the rest; within this ball are three different substances, called humours.

The first, or outer coat, is called the *sclerotica*; the second, or middle one, is called the *choroides*; the interior one is named the *retina*.

Sclerotica. Cornea.

The exterior membrane, which incloses and covers the whole eye, is called the *sclerotica* and *cornea*: it is, however, strictly speaking, but one and the same membrane, with different names appropriated to different parts: the hinder and opaque part being more generally denominated the *sclerotica*, the fore and transparent part the *cornea*.

The *sclerotica* is hard, elastic, of a white colour, resembling a kind of parchment; the hinder part is very thick and opaque, but it grows gradually thinner as it advances towards the part where the white of the eye terminates. The fore part is thinner, and transparent; it is also more protuberant and convex than the rest of the eye, appearing like a segment of a small sphere applied to a larger, and is called *cornea* from it's transparency. The *cornea* is thick, strong, and insensible; it's transparency is necessary for the free admission of the light. This membrane is composed of several plates, laid one over the other, replenished with a clear water, and pellucid vessels; these plates are more evidently distinct in the fore than the hinder part. The *sclerotica* is embraced on it's outside by six muscles, by which the eye may be moved in any direction.

Choroides. Uvea. Iris.

Under the *sclerotica* is a membrane, known by the name of the *choroides*; it is a soft and tender coat composed of innumerable vessels; it is concentric to the *sclerotica*, and adheres closely to it by a cellular substance, and many vessels. This membrane is outwardly of a brown colour, but inwardly of a more russet brown, almost black. Like the *sclerotica*, it is distinguished by two different names, the fore part being called the *uvea*, while the hinder part retains the name of the *choroides*.

The fore part commences at the place where the cornea begins ; it here attaches itself more strongly to the sclerotica by a cellular substance, forming a kind of white narrow circular rim: the choroides separates at this place from the sclerotica, changes it's direction, turning, or rather folding, directly inwards, towards the axis of the eye, cutting the eye as it were transversely: in the middle of this part is a round hole, called the pupil, or sight of the eye: the pupil is not exactly in the middle of the iris, that is to say, the centers of the pupil and iris do not coincide, the former being a little nearer the nose than the latter.

This part, when it has changed it's direction, is no longer called the choroides ; but the anterior surface, which is of different colours, in different subjects, is called the *iris*; the posterior surface is called the *uvea*, from the black colour with which it is painted. The iris has a smooth velvet-like appearance, and seems to consist of small filaments regularly disposed, and directed towards the center of the pupil.

The eye is denominated blue, black, &c. according to the colour of the iris. The more general colours are the hazel and the blue, and very often both these colours are found in the same eye. It has been observed, that in general those, whose hair and complexion are light-coloured, have the iris blue or grey; and on the contrary, those whose hair and complexion are dark, have the iris of a deep brown: whether this occasions any difference in the sense of vision, is not discoverable. Those eyes which are called black, when narrowly inspected, are only of a dark hazel colour, appearing black, because they are contrasted with the white of the eye. "The black and the blue are the most beautiful colours, and give most fire and vivacity of expression to the eye. In black eyes there is more force and impetuosity; but the blue excel in sweetness and delicacy."

The pupil of the eye has no determinate size, being greater or smaller, according to the quantity of light that falls upon the eye. When the light is strong, or the visual object too luminous, we contract the pupil, in order to intercept a part of the light, which would otherwise hurt or dazzle our eyes; but when the light is weak, we enlarge the pupil, that a greater quantity may enter the eye, and thus make a stronger impression upon it. This aperture dilates also for viewing distant objects, and becomes narrower for such as are near. The contraction of the pupil is a state of violence, effected

by an exertion of the will: the dilatation is a remission of power, or rather an intermission of volition.* The latitude of contraction and dilatation of the pupil is very considerable; and it is very admirable, that while the pupil changes it's magnitude it preserves it's figure.

Anatomists are not agreed, whether the iris be composed of two sets of fibres, the orbicular and radial, or of either. Haller says, he could never discover the orbicular fibres, even with a microscope; the radial seem visible to the naked eye, and are sufficient to answer all the purposes required in the motion of the iris: when the pupil is contracted the radial fibres are strait, when it is dilated they are drawn into serpentine folds.

In children this aperture is more dilated than in grown persons. In elderly people it is still smaller than in adults, and has but little motion; hence it is, that those who begin to want spectacles, are obliged to hold the candle between the eye and the paper they read, that the strong light of the candle may force their rigid pupils into such a state of contraction, as will enable them to see distinctly. Those who are short-sighted, have the pupils of their eyes, in general, very large; whereas in those whose eyes are perfect, or long-sighted, they are much smaller.

The whole of the choroides is opaque, by which means no light is allowed to enter into the eye, but what passes through the pupil. To render this opacity more perfect, and the chamber of the eye still darker, the posterior surface of this membrane is covered all over with a black mucus, called the pigmentum nigrum. This pigment is thinnest upon the concave side of the choroides, near the retina, and on the fore side of the iris; but is thickest on the exterior side of the choroides, and the inner side of the uvea.

The circular edge of the choroides, at that part where it folds inwards to form the uvea, seems to be of a different substance from the rest of the membrane, being much harder, more dense, and of a white colour; it has been called by some writers the ciliary circle, because the ligamentum ciliare (of which we shall soon speak) arises from it.

* Anatomists observe, that in animals of prey, both beasts and birds, the pupil is round as in man, which fits them to see every way; but in large animals which feed on grass, the pupil is oblong horizontally, for taking in a large circular space of ground: the pupil in animals of the cat kind, which climb trees, and want to look upwards and downwards, is oblong vertically.

Retina.

The third and last membrane of the eye is called the retina, because it is *spread* like a net over the bottom of the eye; others derive the name from the resemblance of the net which the gladiators called *retiarii* employed to entangle their antagonists. It is the thinnest and least solid of the three coats, a fine expansion of the medullary part of the optic nerve. The convex side of it lines the choroides, the concave side covers the surface of the vitreous humour, terminating where the choroides folds inwards. It is an essential organ of vision; on it the images of objects are represented, and their picture formed. This membrane appears to be black in infants, not so black at the age of twenty, of a greyish colour about the thirtieth year, and in very old age almost white. The retina, however, is always transparent and colourless: any apparent changes, therefore, of it's colour must depend upon alterations of the *pigmentum*, which is seen through it.

Optic Nerve.

Behind all the coats is situated the optic nerve, which passes out of the scull, through a small hole in the bottom of the orbit which contains the eye. It enters the orbit a little inflected, of a figure somewhat round, but compressed, and is inserted into the globe of the eye, not in the middle, but a little higher and nearer to the nose; an artery runs through the optic nerve, goes strait through the vitreous humour, and spreads itself on the membrane that covers the backside of the crystalline.

Mons. Mariotte has demonstrated, that our eyes are insensible at the place where the optic nerve enters: if, therefore, this nerve had been situated in the axis of the eye itself, then the middle part of every object would have been invisible, and where all things contribute to make us see best, we should not have seen at all; but it is wisely placed by the divine artist for this and other advantageous purposes, not in the middle, but, as we have already observed, a little higher and nearer to the nose.

Of the Humours of the Eye.

The coats of the eye, which invest and support each other, after the manner of an onion, or other bulbous root, include it's humours, by which name are understood three substances, the one a solid, the second a soft body, and the third truly a liquor. These substances are of such forms and transparency, as not only to transmit readily the rays of light, but also to give them the position best adapted for the purposes of vision. They are clear like water, and do not tinge the object with any particular colour.

Aqueous Humour.

The most fluid of the three humours is called the aqueous one, filling the great interstice between the cornea and the pupil, and also the small space extending from the uvea to the crystalline lens; it is thin and clear like water, though somewhat more spirituous and viscuus; it's quantity is so considerable, that it swells out the fore part of the eye into a protuberance very favourable to vision. The uvea swims in this fluid. It covers the fore part of the crystalline; that part of this humour which lies before the uvea, communicates with that which is behind, by the hole which forms the pupil of the eye. It is included in a membrane, so tender, that it cannot be made visible, nor preserved, without the most concentrated lixivial fluid.

It has not been clearly ascertained whence this humour is derived; but it's source must be plentiful; for if the coat containing it be so wounded that all the humour runs out, and the eye be kept closed for a season, the wound will heal, and the fluid be recruited.

The colour and consistence of this humour alters with age; it becomes thicker, cloudy, and less transparent, as we advance in years, which is one reason, among others, why many elderly people do not reap all that benefit from spectacles which they might naturally expect.

Crystalline.

The second humour of the eye is the *crystalline*, which is as transparent as the purest crystal; and though less in quantity than the aqueous humour, yet it is of equal weight, being of a more dense and solid nature; in consistency it is somewhat like a hard jelly, growing softer from the middle outwards. Its form is that of a double convex lens, of unequal convexities, the most convex part being received into an equal concavity in the vitreous humour.

The crystalline is contained in a kind of case, or capsule, the fore part of which is very thick and elastic, the hinder part is thinner and softer. This capsule is suspended in its place by a muscle called *ligamentum ciliare*, which, together with the crystalline, divides the globe of the eye into two unequal portions; the first and smaller one contains the aqueous humour, the hinder and larger part the vitreous humour. The crystalline has no visible communication with its capsule, for as soon as this is opened the humour within slips clean out.

The crystalline is placed so, that its axis corresponds with that of the pupil, and consequently it is not exactly in a vertical plane dividing the eye into two equal parts; but somewhat nearer the nose. It is formed of concentric plates or scales, succeeding each other, and these scales are formed of fibres elegantly figured, and wound up in a stupendous manner; these are connected by cellular fibres, so as to form a tender cellular texture. Between these scales is a pellucid liquor, which in old age becomes of a yellow colour. The innermost scales lie closer together, and form at last a sort of nucleus, harder than the rest of the lens. The crystalline has no visible communication with its capsule, so that when this is opened, it readily slips out: some say, that a small quantity of water is effused round it. Leeuwenhoeck has computed that there are near two thousand laminæ, or scales, in one crystalline, and that each of these is made up of a single fibre, or fine thread, running this way and that, in several courses, and meeting in as many centers, and yet not interfering with, or crossing each other.

The yellow colour wherewith the crystalline is more and more tinged as we advance in years, must make all objects appear more and more tinged with that colour: nor does our being insensible of any change in the colour

of objects, prove to us that their colour continues the same; for in order that we should be sensible of this change, the tincture must not only be considerable, but it must happen on a sudden, as will be more fully explained hereafter. In the cataract it is opake; the seat of this disorder is in the crystalline lens.

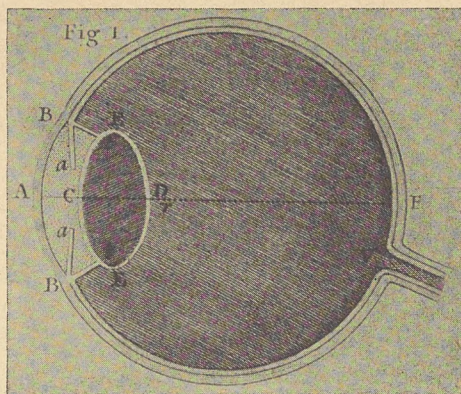
Vitreous Humour.

The vitreous is the third humour of the eye; it receives it's name from it's appearance, which is like that of melted glass. It is neither so hard as the crystalline, nor so liquid as the aqueous humour; it fills the greatest part of the eye, extending from the insertion of the optic nerve to the crystalline humour. It supports the retina, and keeps it at a proper distance for receiving and forming distinct images of objects.

The vitreous humour is contained in a very thin pellucid membrane, and concave at it's fore part, to receive the crystalline; at this place it's membrane divides into two, the one covering the cavity in which the crystalline lies, the other passing above, and covering the fore part of the crystalline, thus forming a kind of sheath for the crystalline. The fabric of the vitreous humour is cellular, the substance of it being divided by a very fine transparent membrane into cellules, or little membranous compartments, containing a very transparent liquor.

Ligamentum Ciliare.

There is still one part to be described, which, though very delicate and small, is of great importance; it is called the ligamentum ciliare, because it is composed of small filaments, or fibres, not unlike the cilia, or eyelashes; these fibres arise from the inside of the choroides, all round the circular edge, where it joins the uvea; from whence they run upon the fore part of the vitreous humour, at that place where it divides to cover the crystalline; those fibres are at some distance from one another, but the interstices are filled up with a dark-coloured mucus, giving it the appearance of a black membrane.



Of the Figure representing the Eye.

Figure 1, represents a section of the eye thro' the middle, by an horizontal plane passing through both eyes; the diameter of the figure is about twice the diameter of the human eye.

The outermost coat, which is called *sclerotica*, is represented by the space between the two exterior circles B F B; the more globular part, adjoining to the sclerotica at the points B B represented by the space between the two circles at B A B, is the *cornea*.

The next coat under the sclerotica is a membrane of less firmness, represented by the two innermost circles of B F B, and called the *choroides*.

Adjoining to the choroides, at B B, is a flat membrane, called the *uvea*. a a is the *pupil*, being a small hole in the uvea, a little nearer the nose than the middle.

V the *optic nerve*; the fibres of this nerve, after their entrance into the eye, spread themselves over the choroides, forming a thin membrane, called the *retina*, and it is represented in the figure by the thick shade contiguous to the circle B F B.

E E is the *crystalline humour*; it is suspended by a muscle B b b B, called the *ligamentum ciliare*. This muscle arises behind the uvea at B B, where the sclerotica and cornea join together at b b, it enters the capsula, and thence spreads over a great part of it's anterior surface.

The *aqueous humour* occupies the space B A B b C b.

The larger space B b D b B F contains the *vitreous humour*.

The foregoing description, we presume, will be found sufficient to give the reader a general idea of the construction of this wonderful organ: for a fuller account we must refer him to the writers on anatomy. Enough has been exhibited to shew with what art and wisdom the eye has been constructed. "And he must be very ignorant of its structure, or have a very strange cast of understanding, who can seriously doubt, whether or not the rays of light and the eye were made for one another, with consummate wisdom and perfect skill in optics."

"If we should suppose an order of beings endued with every human faculty but that of sight, how incredible would it appear to such beings, accustomed only to the slow information of touch, that, by the addition of an organ, consisting of a ball and socket of an inch diameter, they might be enabled, in an instant of time, without changing their place, to perceive the disposition of a whole army, the order of a battle, the figure of a magnificent palace, or all the variety of a beautiful landscape? If a man were, by feeling, to find out the figure of the Peak of Teneriffe, or even of St. Peter's church at Rome, it would be the work of a life-time.

"It would appear still more incredible to such being as we have supposed, if they were informed of the discoveries which may be made by this little organ, in things far beyond the reach of any other sense. That, by means of it, we can find our way on the pathless ocean, traverse the globe of the earth, determine it's size and figure, measure the planetary orbs, and make discoveries in the sphere of the fixed stars.

"Would it not appear still more astonishing to these beings, if they should be further informed, that by means of this organ we can perceive the tempers and dispositions, the affections and passions, of our fellow-creatures, even when they want most to conceal them? that by this organ we can often perceive what is straight and crooked, in the mind as well as the body: that it participates of every mental emotion, the softest and most tender, as well as the most violent and tumultuous: that it exhibits these emotions with force, and infuses into the soul of the spectator the fire and the agitation of that mind in which they originate? To many mysterious things must a blind man give credit, if he will believe the relations of those that see! his faith must exceed that which the poor sceptic derides as impossible, or condemns as absurd.

"It is not, therefore, without reason, that the faculty of seeing, is looked upon as more noble than the other sense, as having something in it superior to sensation, as the sense of understanding, the language of intelligence. The evidence of reason is called *seeing*, not feeling, smelling, tasting; nay, we express the manner of the divine knowledge by *seeing*, as that kind of knowledge which is most perfect in ourselves."*

* Reid's Inquiry into the Human Mind.

Of the Nature and Properties of Light and of Vision.

BEFORE we can attain any satisfactory knowledge of the nature of vision, it will be necessary to point out some of the properties of light.

There is no part of the inanimate creation more wonderful and astonishing than the rays of light, and the phænomena occasioned by them; the knowledge of these properties, and the nature of vision, is with propriety reckoned as one of the most important articles of natural knowledge: it constitutes the science of optics, on whose utility and excellence it would be needless to expatiate, after observing, that to this science we owe the invention of those optical machines, which correct the imperfections of sight, and increase it's natural powers; making us acquainted with beings whose minuteness renders them imperceptible, and bringing to hand objects, whose remote situation affords to the eye either no information, or such as is imperfect and erroneous.

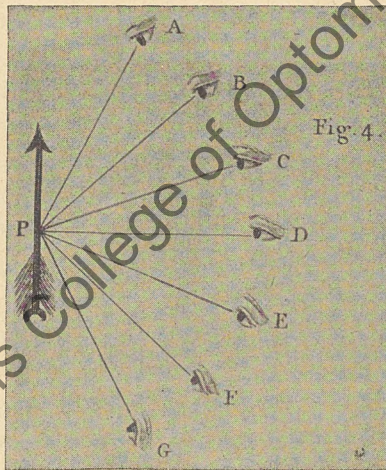
The rays of light are of such extreme minuteness, as to pervade with facility bodies of the closest texture, and greatest density: their velocity is so great, that if the particles of light were equal in mass to the one millionth part of a grain of sand, we should no more be able to endure their impulse, than that of sand shot point-blank from a cannon. The rays cross each other in all directions, without the least disturbance; for through a hole, not exceeding one-hundredth part of an inch in diameter, we can easily view the objects, which occupy almost an entire hemisphere; the light proceeding from all these objects must, therefore, pass at the same time through the hole in a great variety of directions, before they arrive at the eye, and that without interfering with each other, and preventing the sight of the objects. How exquisitely minute must these particles be, that myriads of them can move promiscuously all manner of ways, without impinging one another. That light moves with greater velocity than sound, is known to every one; because the flash of a gun, fired at a considerable distance, will be seen some time before the sound is heard; but sound is known to move at the rate of 1142 feet in a second of time. It was reserved, however, to modern astronomers, to discover with exactness the velocity of light; and from their observations it appears, that it passes through

about one hundred and seventy thousand geographical miles in a second of our time. Milton invokes light in the following sublime manner.

“Hail, holy light, offspring of heav’n first-born;
Or of th’ eternal co-eternal beam
May I express thee unblam’d? since God is light,
And never but in unapproached light
Dwelt from eternity, dwelt then in thee,
Bright effluence of bright essence increate.
Or hear’st thou rather pure ethereal stream,
Whose fountain who shall tell? before the sun,
Before the heavens thou wert, and at the voice
Of God, as with a mantle, didst invest
The rising world of waters, dark and deep;
Won from the void and formless infinite.”

Whatever is seen or beheld by the eye, is by opticians called an *object*.

They consider every object as made up of a vast number of minute points, and that each of these points, by an unknown power, sends forth or reflects rays of light in all directions, and is thus the center of a sphere of light, extending indefinitely on all sides.



To render this plainer, let us suppose one point of an object to be singled out from the rest, and represented by P, fig. 4, then the lines proceeding from it may be considered as the rays of light. Now it is evident, by inspecting the figure, that in whatever position the eye be placed, whether at A, at B, or C, &c. the point will be visible, rays being sent from it to every part.

It appears further, from all experiments that have hitherto been made, that the rays of light proceed from every point of an object in strait lines; but that they are refracted or bent out of this rectilinear course, whenever the density of the medium, through which they pass, is increased or diminished.

By a *medium*, in the language of opticians, is meant any transparent substance, solid or fluid, through which light passes.

One medium is said to be more dense than another, when it contains more matter in the same bulk or size: thus glass is more dense than water, water is more dense than air.

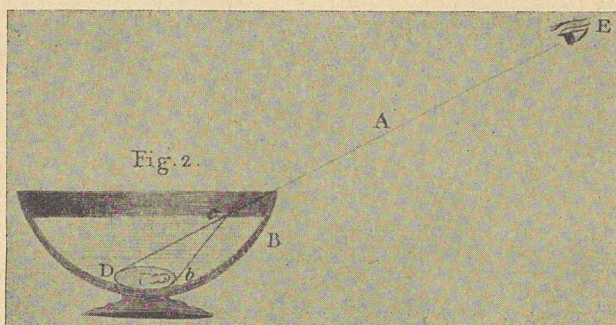
Light is more refracted, or bent, in passing from air into glass, than from air into water; or, in other words, the denser the medium is, the more the rays are bent, and approach a perpendicular let fall from it's surface. An increase of density is not the only circumstance which augments the refracting power of bodies, a similar effect is produced by an increase of inflammability.

The direction with which the rays of light fall on any medium, is as much to be considered as it's density.

For if a ray falls perpendicularly on the surface of any medium, it is not bent, but goes on in the same direction in which it entered, the refraction only taking place when the rays fall obliquely, and is so much greater, as the incidence is more oblique, and the medium is more dense. Thus, for example, the rays are more bent in passing from air into glass, than from air into water.

The following pleasing and easy experiment will give the reader a clear idea of what is meant by the refraction of the rays of light; a wonderful property, to which we are indebted for all the advantages of vision, and the assistance received from glasses.

Experiment. Into any shallow vessel (a bason) put a shilling, and retire to such a distance as that you can just see the farther edge of the shilling, but no more: let the vessel, the shilling, and your eye, remain in the same situation, while an assistant fills up the vessel with water, and the whole shilling will then become visible.



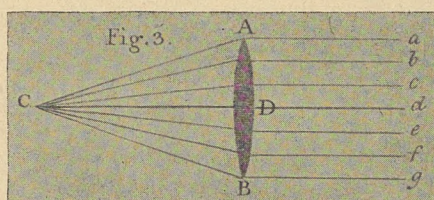
Thus the eye E, fig. 2, can see no part of the piece of money b D in an empty bason B; but pour water into the bason up to c, and the whole piece will be seen; because the ray A c D, which was strait before, is now bent into the form A c B.

For the same reason, a strait stick put partly into water appears bent.

Every ray of light carries with it an image of that point from which it proceeded. If, therefore, all the rays coming from any point, can be united in the same order in which they were emitted, there will be a perfect representation or image of the object, at the place where they are thus orderly united.

The whole apparatus of the eye is designed to produce this orderly union of the rays. The same purpose is also effected by means of convex lenses.

It is by the refraction of the rays of light, that this union is brought about. We have already observed, that if a ray of light falls perpendicularly upon the surface of any medium, it will continue to go on in a straight line, in the same direction it was moving in before; but if it falls obliquely upon the surface of the second medium, it will be refracted at the point of incidence, so as to be bent towards the perpendicular, when it passes out of a thinner into a more dense one; and from the perpendicular, when it passes out of a denser into a thinner medium.



The parallel rays, fig. 3, a b c d e f g, falling obliquely on the surface A D B of a double convex lens, are refracted or bent inward, by passing through the lens, and meet in a focus, or point, at C, which is the center of the lens's convexity.

The middle ray d D falling perpendicularly on the surface of the lens at D, suffers no refraction in passing through it.

By this means, if a number of rays, proceeding from any one point, fall on a convex spherical surface of glass, they will be bent or refracted, so as to be nearly united in a point behind the glass, and there form a representation of the original point.

Hence, when the rays which come from all the points of an object, meet again in as many points, after they have been re-united by refraction, they will at these points of re-union form a picture of the object upon any white body on which they fall.

An easy and very simple experiment will enable the reader to comprehend this part, better than any explanation in words.

Experiment. Let B B, fig. 5, represent a darkened room, or box, into which no light is admitted but what comes through a glass lens at O. Let D E F be objects without doors.

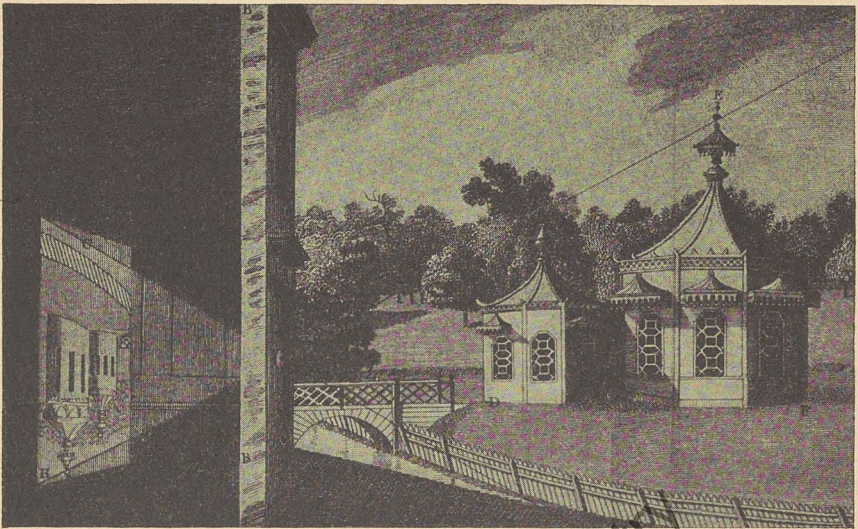


FIG. 5.

The rays of light coming from the objects will be turned out of their course by the refractive power of the lens, and be made to unite at the focus of the lens.

If, therefore, a piece of white paper* be held at the focus, the pictures of the objects will be fairly and orderly represented on the paper, in their natural colours and proportions, but in an inverted situation.

* The picture appears best upon white, because white bodies reflect light of all the different colours more copiously, and more equably than bodies of any other colour.

Every physical point of the objects sends forth it's cone of rays, which, by means of the lens, are made to unite orderly at C H, and being there reflected by the paper, the image of the whole object is distinct and visible, like a picture drawn upon canvas, but much more lively and distinct than the best finished drawing of the finest artist.

If the paper be removed nearer to, or farther from the lens, the picture will be confused; because the rays proceeding from the next adjacent points of the objects, begin to interfere, and mix together.

The distinctness of the picture depends upon the separation of the rays belonging to every point of the object, upon their reception by the paper.

If the paper be removed farther and farther from the focus, the picture will become more and more indistinct, and at length totally vanish, no one part being distinguishable from the rest, because the rays from remote parts are mixed with the others. It is for the same reason, that the room must be dark, otherwise the foreign light, by mixing with the pencils that form the picture, will so weaken it, that at last, as the light grows stronger, it will become insensible, being effaced by the adventitious rays.

The cause of the inversion of the image is evident from a bare inspection of the figure; and it is plain, that this inversion is not to be attributed to the lens: for if the lens be removed, and the light be admitted into the room by a hole of about one-tenth of an inch diameter, we shall have, on the paper, an inverted, though imperfect, picture of the objects without, in the same manner as when the light comes through the lens.

In both cases the several pencils of rays necessarily cross each other; but without the lens, the picture will be faint and confused: it is faint, because there are but few rays for forming each point of the image; whereas the lens collected many together in one point, and thus rendered the image stronger; the picture is confused, because the rays that proceed from adjacent objects interfere, and mingle together.

By the lens, a great number of rays are united in the same sensible point, and this is the principal use of it; and the image is brighter, in proportion as there are more rays united; and more distinct, in proportion as the order in which they proceed is better preserved in their union.

Of Vision.

The foregoing representation of objects upon a sheet of paper, by means of a lens placed at a hole in a window-shutter, is exceedingly similar to what happens to our eyes when we view objects. For vision, so far as our eyes are concerned, consists in nothing but such a refraction of the rays of light by the transparent skins and humours of the eye as will form a distinct picture of the object on the retina. For the structure of the eye plainly indicates, that in order to attain distinct vision, it is necessary that a certain quantity of rays from every visible point of an object should be united at the bottom of the eye, and that the points of union of the rays of the different pencils should be as distinct and separate as possible.

The eye is admirably contrived for effecting these purposes: all the rays coming from any visible point of an object, that can enter the pupil, are united closely together upon the retina, and thereby make a much more powerful and stronger impression than a single ray alone could do; to answer this purpose, the retina is placed at a proper distance behind the refracting surfaces, and each pencil of rays is refracted orderly into distinct focuses, that the whole object may be distinctly seen at the same instant.

These effects are owing to the refraction of the rays of light; for if these rays were not so refracted, very few of them would strike upon the least sensible point of the visionary nerve, and the rays from different objects, or from different parts of the same objects, would strike at the same place at once, and thus create an indistinctness equal to blindness.

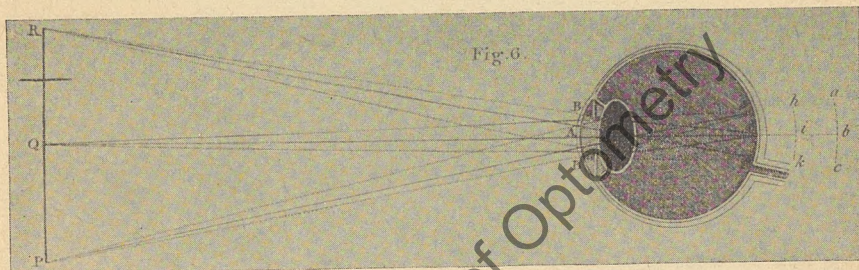
When the light is weak or strong, the pupil is accordingly enlarged or contracted, for the admission of more or fewer rays, that the impressions on the retina may be rendered suitable to the respective cases.

As the crystalline humour is densest in the middle, it is highly probable that it is not equally refractive. This difference in density of the constituent parts of the crystalline is admirably contrived for correcting the aberration from it's figure, as well as that of the cornea. The more remote rays of each pencil, by passing through a medium, gradually diminishing in density from the middle towards the extremes, have their focuses gradually length-

ened, which correct the aberrations of the figure, that so they may unite nearer together. The concave figure of the retina is somewhat serviceable for the same purpose.

It is by no means easy to determine with accuracy the measure of refraction of the different humours of the eye; from such experiments as could be made, it has been found that the refractive powers of the aqueous and vitreous humours are much the same with common water, and that of the crystalline a little greater.

The cornea and aqueous humour being supposed to have the same refractive powers, all three may be considered as one dense medium, whose refractive surface is the cornea; and the crystalline humour may be considered as a convex lens, placed in a given position, within the said medium. Whence the humours of the eye all together make a kind of compound lens, whose effect in refracting rays having a given focus of incidence, is easily found by the laws of optics.



We shall now endeavour to explain the action of the rays of light upon the eye, by a figure. Let P Q R, fig. 6, be an object; then the pencils of light B P B, B Q B, B R B from the points P Q R, are first refracted by the cornea, so as to belong to the focuses a b c, behind the eye; then by the anterior surface of the crystalline humour, they are again refracted towards the focuses h i k, nearer to the eye than before; and lastly, in going out of the crystalline into the vitreous humour, they are again refracted, so as to unite in the points p q r. In like manner, the pencils

of rays coming to the cornea from every physical point of the object P Q R, are, by the different refracting surfaces of the eye, brought orderly to unite upon the retina, and there form, as it were, an image p q r of the object, but in an inverted position; the upper part of the object being painted upon the lower part of the retina, the right side of the object upon the left side of the retina, and so of other parts. Thus the cavity of the eye is a kind of *camera obscura*, the cornea and crystalline making a sort of compound lens, whose aperture is limited by the breadth a a of the pupil. And that the parts of the eye are adapted to produce such an image, may be proved by experiment: for if the tunica sclerotica be taken away from the back of an eye, newly taken out of the head of any animal, and this eye be placed in a hole made in the window-shutter of a dark room, so that the bottom of the eye be towards you, a beautiful, but inverted, picture of external objects will be exhibited, painted in the most lively colours.

If the humours of the eye, by age, or any other cause, shrink and decay, the cornea and crystalline grow flatter than before; and the rays not being sufficiently bent, arrive at the retina before they are united in their focus, and meet in some place behind it, and therefore form an imperfect picture at the bottom of the eye, and exhibit the object in a confused and indistinct manner: this defect, of which we shall treat more particularly hereafter, is remedied by spectacles with convex glasses, which, by increasing the refraction of the rays of light, cause them to converge more, and thus convene distinctly at the bottom of the eye.

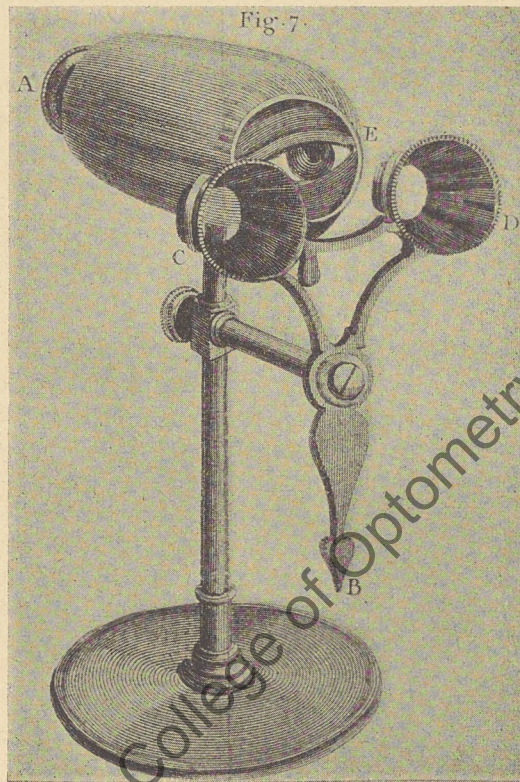
On the other hand, if the cornea and crystalline be too convex, the rays unite before their arrival at the retina, and the image thereon is of course indistinct: this defect, like the preceding one, may be remedied by the use of glasses, though of a contrary figure, for here they must be concave, instead of convex; a lens, of a proper concavity, placed before the eye, will make the rays diverge so much more than they do in their natural state, as will cause them to meet at the retina.

Of the Artificial Eye.

If the eye of an animal be taken out, and the skin and fat be carefully stripped off from the back part of it, till only the thin membrane which is called the retina, remains to terminate it behind, and any object be placed

before the front of the eye, the picture of that object will be seen figured as with a pencil on the retina. There are thousands of experiments which prove that this is the mechanical effect of vision; but none of them which render it so evident as this with the eye of an animal: an eye of an ox newly killed, shews it happily, and with very little trouble.

The optical effects of vision may be very pleasingly and satisfactorily illustrated by the instrument represented at fig. 7, which is called an *artificial eye*.



At the end E there is a piece of glass placed, on which the form of the eye is painted, a part being left transparent, to represent the pupil; within the globe are inserted three lenses, of different convexities, either

of which may be brought opposite to the hole, or pupil; one of these is to answer for the natural state of the eye; the other being less convex, is to shew the state of the eye when flattened by age; the third, more convex than the first, to represent the condition of the short-sighted: at the opposite end A of the globe is a greyed or semi-transparent piece of glass, to represent the retina.

At the front are two lenses, fitted into frames, and moveable by the handle B, one concave, C, and the other convex, D, which may be occasionally placed before the eye, to shew how the imperfect states of it are remedied.

If the artificial eye be turned towards any bright object, at a moderate distance, and the lens for the natural sight be brought before the pupil, a lively and distinct, though inverted, picture of the object will be exhibited on the greyed glass. If you take the eye in your hand, you will see a bright vivid image of the window on the greyed glass.

If either of the other lenses be placed opposite the pupil, the picture becomes confused; shewing, that when the eye has it's due form and figure it has no occasion for lenses.

To represent a *long-sighted eye*, bring the glass which is less convex than the first, to coincide with the pupil, and you will find the image very imperfect on the greyed glass; but by applying the convex lens, which will cause the rays to converge, you will obtain a perfect image of the object. Now remove the glass that is behind the pupil, and bring forward in it's place the lens which is more convex, this will represent the cornea of a *short-sighted eye*, as well as it's effect in forming the image short of the retina, and if you hold it up towards the window, you will find that no image of the window is formed, nor can any object at a distance have it's image formed with distinctness in this case; but put the concave glass before it, and this by rendering the rays less convergent will make the rays unite at the retina, and form as perfect an image as before.

Of the inverted Position of the Image.

If vision be owing to the picture on the retina, it may be asked, why the object appears in it's natural *upright position*? how, when nature draws the picture the wrong way, her errors are so readily corrected?

If it were as easy a task to give a satisfactory explanation of this abstruse question, as it is to start objections to every system hitherto suggested, to account for the operations of the mind on the body, and the body on the mind, it would have been explained long ago.*

The difficulty would be still greater, if it was the picture we saw, and not the object; but the picture *is not seen at all*, the eye can see no part of itself; the picture is the instrument, by means of which the object is perceived; but it is not perceived itself, the instrument neither perceives, compares, nor judges; these are powers peculiar to that psychological unity which we call the *mind*.

It is absolutely necessary, in considering this subject, to distinguish between the organ of perception, and the *being* that perceives. A man cannot see the satellites of Jupiter, unless assisted by a telescope: does he therefore conclude from this, that it is the telescope that sees those satellites? By no means; the conclusion would be absurd: nor would it be less absurd, to conclude that it is the eye that sees: the eye is a natural organ of sight, but the natural organ sees as little as the artificial.

Our senses are instruments, so framed by the Author of our being, that they correspond with, or have a determined relation to, those qualities in objects which they are to manifest to us. It is thus with the eye; it is an instrument most admirably contrived for manifesting visible objects to the mind; for this purpose, it refracts the rays of light, and forms a picture upon the retina; but it neither sees the object, nor the picture. The eye will refract the rays of light, and form the picture, after it is taken out of the head, but no vision ensues. Even, when it is in it's proper place, and perfectly sound, an obstruction in the optic nerve takes away vision, though the eye has performed all it's functions.

We know, indeed, how the eye forms a picture of visible objects on the retina; but how this picture makes us see objects, we know not: and if experiment had not informed us that such a picture was necessary, we should have been entirely ignorant of it. The seat of sensation, wherever it is placed, does not appear to be passive in receiving images; the images are the occasion of it's re-action, and directing a ray from itself towards

* See, on this subject, Reid on the Mind, Potterfield on the Eye, Hartley on Man, Bonnet's *Essai Analytique sur l'Ame*, Berkeley on Vision, &c. &c.

every object it perceives, and this action and re-action are reciprocal. Hence we often see objects when the eye is turned from them, and often do not see the object on which the eye is turned, if the attention be otherwise engaged.

The pictures upon the retina are, however, a mean of vision; for such as the picture is, or such as the action of the rays of light is on the retina, such is the appearance of the object in colour and figure, distinctness or indistinctness, brightness or faintness; but as we are totally ignorant of the mechanism or the mind, or of the organization of the mental eye, we cannot say how this effect operates, and can only conclude, that the natural eye is an instrument of vision.

It appears very clear from Dr. Darwin's experiments, that the retina is often in an active state, and that upon the activity of this organ many of the phenomena of vision depend; an impression on the retina being first made by an active power, which produces a conformable change and re-action, that passes directly to the sensorium, occasioning, though in an unknown manner, the perception of objects.

On a subject, therefore, confessedly so obscure, and which is perhaps beyond the limits of human conception in its present state, every explanation must be imperfect, every illustration inadequate. Among the various attempts of human sagacity, to shew why an *inverted image* is the mean of exhibiting objects to the mind in an upright position, the following is perhaps one of the least imperfect.

Every point of an object is seen in the direction of a right line, passing from the picture of that point on the retina, through the center of the eye, to the object point; and, therefore, such points indicate to the mind the existence of the object point, and its true situation; and of course, that the object, whose picture is lowest on the retina, must be seen in the highest direction from the eye; and that object, whose picture is on the right of the retina, must be seen on the left: so that by a natural law of our constitution we see objects erect by inverted images, and if the pictures had been erect on the retina, we should have seen the object inverted.*

* Reid on the Human Mind.

But supposing the preceding illustration to be the true one, and quite satisfactory, many difficulties still remain, to perplex the philosopher, and embarrass the anatomist. There are parts of the eye which assist in perfecting the organ of vision, whose nature and functions are among the desiderata of science. We are ignorant of the office of the optic nerve, or in what manner it performs that office. That it has some part in the faculty of seeing, is evident; because in an amaurosis, which is said to be a disorder of the optic nerve, the pictures on the retina are clear and distinct, and yet there is no vision.

We know still less of the use and functions of the choroid membrane; it is necessary, however, to vision; for it is well known, that a picture upon that part of the retina where it is not covered with the choroid, namely, at the entrance of the optic nerve, produces no more vision than a picture upon the hand.† There are, therefore, other material organs, whose operations are necessary to seeing, even after the pictures upon the retina are formed; whenever we become acquainted with the use of these parts, more links of the chain will be brought into our view, and we shall better comprehend this wonderful instrument.

Having had occasion to mention that there is no vision produced by that part of the retina which is not covered by the choroid membrane, it will be proper to illustrate this circumstance more fully, and shew in what manner this fact has been ascertained, the discovery of which occasioned a long controversy concerning the proper seat of vision.

Experiment. Fix three black patches, A, B, C, upon a white wall, at the height of the eye, A being to the left, and C to the right: place yourself facing these patches, shut the right eye, and direct the left towards the patch C, you will then see both A and C, but the middle patch B will disappear. Or if the left eye be shut, and the right directed towards A, you will still see both A and C, but B will disappear. If the eye be directed towards B, both B and A will be seen, and not C; for which ever of the patches is directly opposite to the optic nerve vanishes. This experiment is rather difficult at first, but becomes easy by a little practice. In our usual intercourse with common objects, we are not sensible to this

† This is not conclusive, for where there is no choroid, there is no retina, the optic nerve being not yet expanded into that membrane. If the choroid was taken away from behind the retina, there is reason to believe that vision would still take place.

defect, because we turn the visual parts of the eye with so much rapidity upon the invisible part of the object, that the loss, without peculiar attention, is imperceptible; this loss, however, in one eye, is remedied by the use of both, as the part of the object that is not seen by one, will be distinctly perceived by the other. This defect of sight, though common to every human eye, was never known, until it was discovered by the sagacity of Mons. Mariotte in the last century.

Of the Extent or Limits of Vision.

We shall now proceed to consider further the nature, properties, and extent of power of the eyes. As in a dark chamber, a very slender beam of light is visible; so in all cases when the surrounding medium is very dark, objects are seen by small quantities of light. Hence, when the medium round the eye is dark, a small quantity of light will suffice for vision, the eye being, by the exclusion of the adventitious light, rendered sensible to the most delicate impressions.

The extent, therefore, of our sight is increased or diminished, in proportion to the quantity of light that surrounds us, supposing the illumination of the object to remain the same. Hence it has been calculated, that if the same object, which during the day we see at the distance of 3436 times it's diameter, were equally illuminated during the night, it would be visible at 100 times greater distance.

Thus in a dark night the feeble light of a candle may be seen at a great distance; and the fixed stars, though they have no sensible diameter, are visible, and the darker the night, the more of them are seen. A certain quantity of light is, however, necessary, even in this case, for vision; for the impressions of light from the satellites of Jupiter and Saturn, are too feeble to be perceived without the assistance of a telescope.

At the approach of day, and as the twilight increases, the eye begins to be enlightened by the reflection of the atmosphere, the stars grow fainter, and in proportion as the light increases, gradually disappear, first those of the least, and at last those of the largest magnitude. As the day advances, the moon herself loses of her lustre, till at length her light is overpowered, and she is no longer seen. In the same manner, small particles are seen

floating in a beam of light let into a darkened room, but as soon as the room is enlightened, those particles disappear.

One of the reasons why we are often unable to distinguish distant objects, is the profusion of rays reflected from intermediate objects, which, by their brilliancy, prevent us from perceiving the fainter rays that proceed from those which are more distant, so that when the objects are very remote, their picture on the retina is easily obliterated, by the vigorous and lively impressions made by those that are nearer. But when the intermediate ones emit a feeble light, when compared to that which proceeds from the more remote ones, these will form a distinct picture on the retina, and become perfectly visible.

The extent of vision is not only limited by the light of the ambient medium, which enters the eye with the pencils of light that proceed from surrounding objects ; but it is further impeded by the heterogeneous particles that are constantly floating in the air : these, by their opacity and reflective power, form a kind of veil, that obscures the vision of remote objects ; and the more the medium is loaded with these particles, and the more remote the object is from the spectator, the more obscure and indistinct it will appear, and the limits of vision be more confined.

The exhalations which continually rise from the earth, augment this obscurity, and render the air less transparent, especially near the earth ; the celestial bodies generally, therefore, appear more obscure when near the horizon, than when they are at a greater elevation ; because, in the first case, they are seen through that part of the atmosphere which is contiguous to the surface of the earth ; but in the latter, through a part which is at a greater distance.

Every one knows, that objects at a given distance are more distinctly seen, and are visible at a greater distance in clear, than in foggy weather. Thus early in a clear morning, and when the air is free from vapours, and not much enlightened, a hill or a head-land is visible at a great distance ; but as the day advances, the land becomes more obscure, till at length, by the great opacity of the intervening vapour, and the light reflected by it to the eye, the object becomes less and less perceptible, and at last totally disappears. Hills, and other high lands, are seen more distinctly in the

morning, partly from this circumstance, that by their elevation they are more illuminated than the parts intervening between them and the spectator.

But the obscurity arising from the exhalations is not the least part of the inconvenience they occasion; the rising exhalations have a kind of undulating motion, like that of smoke or steam, so that objects seen through them appear to have a tremulous or dancing motion, which is sensible even to the naked eye: if distant objects be viewed on a hot summer's day, this effect is so sensible in telescopes, as to render them entirely useless for terrestrial objects, when they augment apparent magnitude more than eighty times.

From this want of transparency in the atmosphere, arises that gradual diminution in the light of objects, which painters call the aerial perspective, by which they endeavour to give that degradation of colour, and indistinctness of outlines, peculiar to objects at a distance: for if the air were perfectly transparent, an object would be equally luminous at all distances, because the visible area and the density of light decrease in the same proportion.

Another cause which limits the extent of vision, and for the removal of which optical instruments are more particularly adapted, is their smallness in proportion to their distances: for excepting in the case of luminous objects seen in the dark, it is necessary that an image on the retina should have some determinate magnitude, in order to become perceptible; thus a house may be seen at a considerable distance, but we must approach nearer before the windows are discernible, and nearer still to distinguish the bricks.

It is not easy to determine with accuracy the quantity of the *minimum visible*, or the angle that is subtended by the smallest visible object. Mr. Harris has inferred, from several experiments, that objects are seldom visible under an angle less than 40 seconds, and at a medium not less than two minutes.

A simple object, as a white or black square, upon the opposite colour, is perceivable under a less angle than the parts of a compound one. The more objects differ in colour, the more easily we can distinguish their several

impressions on the retina: different degrees of light on the same object will render it visible at different distances, and under different angles; indeed the most general cause of the non-visibility of objects, is the want of sufficient light in the pencils that proceed from them; several contiguous objects are scarce discernible one from the other, unless they each subtend angles that are not less than four minutes.

A long slender object is visible under a smaller angle than a square object of the same breadth: a slender object, as a line, may be considered as consisting of several squares joined together; and though one of these squares may be too small to be seen, yet the pencils of light coming from each of them being contiguous, and striking at the same time upon the retina, are capable, by their united strength, to awaken the visive faculty, and so to render the objects visible from whence they came. For the same reason, *a small object in motion* is easier discerned than if at rest, and may be visible in the one case, though not in the other. A small star, by day or twilight, that cannot be easily seen through a telescope directed to it, will become visible by shaking or moving the telescope.

There is a great difference in the degree of sensibility of different eyes. We have been told of persons seeing a satellite of Jupiter without the assistance of glasses: a circumstance that to many appears incredible. But when we consider how much the various circumstances of light affect vision, and how much further our sight is extended at some favourable opportunities than at others, these extraordinary accounts may be the more readily credited.

The following calculation of M. de la Hire will give some idea of the extreme sensibility of the optic nerves. The sail of a windmill, six feet in diameter, may be easily seen at the distance of 4000 toises, and the eye being supposed to be an inch in diameter, the picture of this sail at the bottom of the eye will be the eight thousandth part of an inch. This shews with what wonderful accuracy the rays of light are refracted by the eye, so that a pencil of rays coming from one point of the object, shall meet in a point on the retina, so as not to deviate the eight thousandth part of an inch.

If an object be held too close to the eye, it becomes indistinct, and the more so the closer it is held, notwithstanding it's apparent magnitude is thereby increased, and a very slender object will become totally invisible.

To the generality of eyes, the nearest distance of distinct vision is about seven or eight inches; at this distance they commonly read a small print, and examine all minute objects. It is true some eyes can see small objects best at the distance of six, four, and even three inches; and some again at twelve, fifteen, or twenty inches; but these are only particular cases, and do not, therefore, affect the present inquiry.

Of distinct and indistinct Vision.

It will be proper in this place to explain, with more accuracy, what is meant by distinct vision, and what is the difference between seeing an object distinctly, and seeing it clearly; as the clearness or brightness with which an object is seen, is often confounded with distinct vision.

We see an object *clearly*, when it is sufficiently illuminated, to enable us to form a general idea of it's figure, and distinguish it from other objects: we see it *distinctly*, when the outlines of it are well defined, when we can distinguish the parts of it, and determine their colour and situation. Thus we may be said to see a distant object *clearly*, when we can perceive that it is a tower; but to see it *distinctly*, we approach so near as to be able to determine not only it's general outline, but to distinguish the parts of which it is composed.

This may be made more evident, by adverting to the experiment of the dark chamber, in which we shall find a considerable difference between the distinctness and brightness of the picture; and learn, that a confusion of the parts is not the same thing with obscurity.

For the picture may be distinct in all it's parts; the rays which come from one and the same point in the object, may be exactly collected into one and the same point upon the paper; and yet, if but few rays pass through the lens, and consequently the space where the picture is painted should be but faintly enlightened, this picture, though it is distinct, will be faint and obscure. On the other hand, though the picture be confused, either because the paper is placed at an improper distance from the lens, or for any other cause; yet if many rays pass through the lens, and strongly illuminate the paper, the picture, notwithstanding the want of distinctness, will be a bright one.

The brightness or clearness with which an object is seen, depends principally on the following circumstances.

1. On the quantity of light proceeding from the object to the eye, and this is in a great measure regulated by the distance, for the intensity of light diminishes in an inverse ratio to the square of the distances.

2. It depends on the colour of the object itself, and of those objects which surround it.

3. On the manner in which the light falls upon the object, and is reflected from it.

4. On the aperture of the pupil, for the wider this is, the greater will be the number of rays that are transmitted to the retina.

5. On the transparency and purity of the humours of the eye, and the soundness of the rest of the visive parts.

6. On the transparency of the atmosphere.

When all these circumstances concur, an object will appear bright and clear; but less so, in proportion as any of them are wanting. In order, however, to obtain distinct vision, it is requisite, not only that the object be sufficiently illuminated, but also that the several pencils, on their arrival at the retina, should be separate, and not mixed together, and when this is not the case, the outlines of the object and its parts will appear faint, hazy, and ill-defined. We may, therefore, consider the *following conditions as necessary towards obtaining distinct vision.*

1. The objects should be sufficiently illuminated: now all other circumstances being the same, the nearer an object is, and the brighter its colour, the more light the eye receives from it; this is one reason why near objects are more distinctly seen than those that are remote.

2. The geometrical image, of objects should fall either upon the retina, or very near it, and these images should be sufficiently large, otherwise the parts of the object cannot be distinctly perceived: the want of size in this image is also a cause of the indistinctness of remote objects.

3. It is also requisite that the eye be in perfect order, and its humours transparent, in order that the impressions of light may be lively and distinct.

In a given eye, and a given disposition of that eye, an image upon the retina will be most perfect when the object is at some determinate distance from the eye, and it is near this point or place, that objects, if they are not too small, will be distinctly seen. An object at a greater or less distance, will have its image either before or behind the retina; and in either case, if the distance of the image from the retina be considerable, the vision will be indistinct.

Dr. Jurin has, however, shewn that it is not necessary to distinct vision, that the images of objects, or the points of union of the rays be precisely upon the retina, there being some latitude both before and behind the retina, within which, whatever images be formed, the vision will be equally distinct, and this latitude will be greater or less, according as the visual angles, subtended by the respective objects, are greater or less.

Let a printed page, in which there are letters of three or four different sizes, be placed at such a distance, that every sort of print may, without any straining or effort of the eye, be perfectly distinct; in this case it may be reasonably presumed, that the images of the several letters fall upon the retina. If the printed leaf be brought gradually nearer and nearer, the smallest print will first begin to be confused, whilst the larger remains as distinct as before: by advancing it still nearer, the smaller print will become more confused, the next size above it a little confused, whilst the large print is still as legible as before, and so through several degrees, till the whole is in confusion.

The same experiment may be made the contrary way, by using a pair of spectacles, of a proper convexity. From hence it is evident, that we may have distinct vision, when the focuses of the pencils are at some distance, either before or behind the retina, and that the larger the object, the greater is this latitude.

But as in this case the pencils from every point either meet before they reach the retina, or tend to meet beyond it, the light that comes from them must cover a circular spot upon it, and will, therefore, paint the image larger than perfect vision would represent it: and consequently, every object, placed either too near or too remote for perfect vision, will appear larger than it is, by a penumbra of light, caused by the circular

spaces, which are illuminated by pencils of rays proceeding from the extremities of the objects. These circular spaces are called circles of dissipation. This accounts for short-sighted persons finding near objects appear rather magnified, when they use a concave that is not so deep as that to which they are accustomed.

On account of these penumbrae, it is clear that two stars will appear to be nearer than they really are; and if they be really very near, will appear to be but one, but brighter than either of them taken alone: so that the two stars will have the same appearance as if one brighter star appeared in the middle of the space occupied by two stars.

When objects are large, they will appear tolerably distinct at a much less distance than small objects, because the penumbrae will not interfere so much. For this reason, a large print may be read much nearer the eye than a small one; the former will appear only ill-defined, but sufficiently distinct, when the latter is quite indistinct, the penumbra of one letter interfering with *that* of another.

It is very difficult to ascertain precisely the natural distance of distinct vision, or that distance at which the eye, without any strain or effort, is suited to see objects distinctly. If we suppose this distance to be that at which we usually read a large fair print, this will be about fifteen or sixteen inches, and less it cannot be, as we are rather more concerned with large objects than the letters of a book; and when we view objects nearer, it is on account of their minuteness: nor is it probable that the distance can be many feet, as, in order to examine objects, we are always desirous to have them near the eye, except they are very large. The nearest distance of distinct vision is in general computed to be at about seven or eight inches from the eye. *That point in any object to which the optic axis is directed is seen more distinctly than the rest.* The truth of this position is confirmed by every one's own experience: if we turn our eyes directly toward one particular part of an object so as to look steadily at it, we may indeed, if the object be not very large, see all the rest of it at the same time; but this part will appear more distinct than the rest: but looking steadily at an object is turning our optic axis towards it.

Of the Change in the Conformation of the Eye for distinct Vision, at different Distances.

As a ship requires a different trim for every variation of the direction and the strength of the wind, so, if we may be allowed to borrow that word, the eyes require a different trim for every degree of light, and for every variation in the distance of the object, while it is within certain limits. The eyes are trimmed for a particular object, by contracting certain muscles, and relaxing others; as the ship is trimmed for a particular wind, by drawing some ropes, and slackening others. The sailor learns this trim of his ship, as we learn the trim of our eyes, by experience.*

A ship, although it be the noblest machine that human art can boast, is far inferior to the eye, for it requires art and ingenuity to navigate her, and the sailor must know what ropes to pull, and which to slacken, to accommodate her to a particular wind. But the eye is fabricated with such superior wisdom, and the principles of it's motion so contrived, that it requires no art nor ingenuity to see by it: we have not to learn what muscles we are to contract, nor which we are to relax, in order to fit the eye to a particular distance of the object.

But although we are not conscious of the motions we perform, in order to fit the eyes to the distance of the object, we are conscious of the effort employed in producing these motions, and probably have some sensation which accompanies them, and to which we give as little attention as to many other sensations; and thus a sensation either previous or consequent upon that effort, comes to be conjoined with the distance of the object which gave occasion to it, and by this conjunction becomes one of the signs of that distance.

That we are capable of viewing objects with nearly equal distinctness, though they be placed at considerable distances from each other, is evident; but the alteration which takes place in the eye for this purpose, or the mechanism by which this effect is produced, is not easily ascertained.

It seems clear from the first view of the subject, that when several objects are at different distances before us, they will not appear equally distinct at the same time. Lest it should be suspected that the indistinct-

* Reid's Inquiry into the Human Mind.

ness in this case may be owing to the impressions not being made upon the corresponding fibrils of the two retinas, let us make a trial with one eye alone, while the other is shut; thus place two small objects, as two pins, one behind the other, and let the one be at a foot, and the other at about six inches distance from the eye. Either of these objects, when looked at attentively, will appear distinct; but the other, at the same time, although it be in the axis of the eye, will be confused. And from hence it is very clear, that the same conformation of the eye is not adapted for distinct vision at all distances, and that the eye by some means changes it's conformation, so as it may be better suited for vision at different distances.

In a similar manner to the foregoing experiment, if the eye looks attentively upon the little scratches or particles of dust upon a window-glass, the objects without doors will be indistinct; and when we look at the external objects, the opaque particles upon the glass, which before were distinct, will now be confused. It also frequently happens, that when we first look at an object, it will appear very confused, which confusion will vanish by degrees, and in a little time the object will become quite distinct.

In like manner, if after poring some time on a book, we suddenly look at objects farther off, they will at first appear confused, and become distincter by degrees. A similar indistinctness takes place, when from looking at remote objects, we suddenly look at one that is near. To what can we attribute these phænomena, but to a change in the conformation of the eye for vision at these different distances; a change which requires some small time for it's performance. It cannot be owing to the last impression on the eye not being obliterated; for in that case, the same confusion would be observable upon shifting the eye from one page of a book to the other.

These phænomena are stronger when they happen without our thinking upon them; for when we make the experiment on purpose, and the mind is already prepared for what is to happen, it has time in part to frustrate our design, the more so, as these changes are somewhat painful.

Authors are much divided in their opinions concerning the change that is made in the conformation of the eye, to procure distinct vision at different distances, some thinking it to be a change in the length of the eye, others

that it is a change in the figure or position of the crystalline humour, others that it is a change in the cornea. The authors of each opinion have their objections to all the rest, and perhaps the truth may lie among them all. As the rays of light suffer a greater refraction at the cornea than they do afterwards, it is plain that a less change, as to quantity, in the radius of the cornea, will effect the business, than would be sufficient in any other part of the eye: but at the same time it must also be confessed, that most persons who have been couched for cataracts, are obliged to have glasses of different convexities, in order to have distinct vision at different distances; from whence it seems necessarily to follow, that the crystalline humour is concerned in changing the conformation of the eye. Perhaps the cornea, and the crystalline, if not some other parts of the eye besides, may contribute to produce this effect: and in order to obtain distinct vision at a nearer distance, at the same time the cornea is rendered more convex, the axis of the eye may be a little lengthened, the crystalline made more convex and brought forwarder, all which changes conspire to the same end; and the contrary for obtaining vision at a greater distance.

It has been shewn by writers on optics, that if an object be viewed distinctly at three different distances from the eye, the first of which may be the least distance at which it can be viewed distinctly, the second double the first, and the third infinite, that the alterations in the conformation of the eye, necessary for viewing an object distinctly at the first and second distances, whose difference is but small, are as great as those that are necessary for the second and third, whose difference is infinite.

Hence, if a short-sighted person can read a small print distinctly, at two different distances, whereof the larger is but double the lesser, as great alterations are made in his eyes, as in one whose eyes are perfect, and that can see distinctly at all intermediate distances, between infinity and the largest of the two former distances. For the same reason, a short-sighted person can see distinctly at all distances, with a single concave of a proper figure; for the cause of short-sightedness is not a want of power to vary the conformation of the eye, but that the whole quantity of refractions is always too great for the distance of the retina from the cornea.

We may hence also clearly perceive why our eyes are so soon fatigued in looking at near objects; for in this case, the muscles of the eyes, and the ligamentum ciliare, are obliged to make a considerable effort, to give the

eyes the necessary conformation, which effort being greater in proportion as the object is nearer, must be painful and laborious when the object is very nigh.

When the eye has been attentively fixed on an object at some determined distance, it cannot immediately see another object distinctly; whether it be at a greater or lesser distance, it appears confused and imperfect, till the eye has adapted itself to the distance at which the object is placed.

Of the Pupil of the Eye, and of it's Motions.

In speaking of the structure of the eye, we have shewn that the uvea has a small round hole nearly in the middle, called the *pupil*, through which the rays must all pass before they can get to the bottom of the eye, and paint the images of objects on the retina. The consideration of the various affections of this part of the eye, will be found of great importance, both to the vender and purchaser of spectacles; for upon the state and aperture of the pupil, the requisite degree of magnifying power very much depends.

The author of nature has proportioned the magnitude of the pupil, so that it may best answer the purposes of vision, and the sensibility of the retina: if it were too large, the retina would be fatigued, and hurt by the great quantity of light. Hence it is that those creatures cannot bear the light of day, which, in order to search for and procure their food at night, have the pupil of their eyes very large. Further, if this aperture had been much larger than it really is, the eye would not have been a dark cell, and so much adventitious light would have entered, as to render the picture upon the retina obscure and indistinct: for as in the camera obscura, the pictures are most lively and perfect when all the light is excluded, but what comes from the object, and serves to form the picture; so it is with our eyes; the picture on the retina is most perfect when all extraneous light is excluded, and none mixes with the picture, but what tends to it's formation.

On the other hand, if the pupil had been very small, it would not have admitted a sufficient quantity of light; the impression on the retina would have been weak, and the picture faint and obscure; when the pupil is very small, convex glasses are necessary, in order to increase the quantity of light.

All animals have a power of contracting and dilating the pupil of their eyes. The natural state appears to be that of dilatation, and the contraction a state of violence, produced by an effort originating in the mind. When the light is too strong, or the object too bright, we contract the pupil, to intercept that part of the light which would injure the eye; but when the light is weak, we dilate the pupil, that more light may enter the eye. If a person look towards the sun, you will observe the pupil become exceeding small; but if he turns his eyes from the light, and be gradually brought into a dark place, you will observe the pupil to dilate, in proportion as the light becomes more faint and obscure.

There are also other circumstances which will cause the pupil to contract, as when the object is nearer the eye than the limits of distinct vision: for in this case, the pencils of rays proceeding from the object are too diverging to be united in corresponding points on the retina; but by contracting the pupil, many of the rays are excluded, and the picture is rendered more distinct. It is for this purpose, that many short-sighted persons contract a habit of corrugating their eyebrows in reading, a habit which would be prevented by the use of concave spectacles.

Dr. Jurin has shewn, that the contraction of the pupil does, in general, depend more upon the strength of the light, than on the sensation of confusion in the object. Let any person take a book by day-light, and stand near the middle of a room, with his back to the light, and then hold the book so near, that the letters may appear indistinct, but not so much so, but that they may be read, though with difficulty; on turning towards the light, it will be read with more ease. Again, holding the book at the same distance, go into the darkest part of the room, and standing with your back to the light, you will find the book not at all legible; but on coming to the window, with your face to the light, you will be able to read with ease and distinctness. A person who has used spectacles for some years, will in the sunshine be able to read without them.

When we have been for some time in a place much illuminated, or if the eye has been too long exposed to a resplendent object, and then views objects that are less so, or goes into a darker place, the sight will for a little time be impaired, and the eye unable to perform it's proper functions. The same will also happen from the contrary circumstances, if we go from a

faint light into one that is much brighter; in either case the pupil has not time to conform itself to the sudden,* but necessary change, for seeing distinctly under the new circumstances. From hence we may infer, that very opaque shades round a candle, instead of preserving and protecting the eye, must be necessarily prejudicial to it. A moderate degree of opacity in the shade, as that of thick paper, may, by lessening the degree of light, be useful to eyes which are inflamed or have a tendency to inflammation.

There is a kind of sympathy, or concord, in the motion of the pupils of both eyes, so that when one is contracted, the other contracts also; when one is dilated, the other also dilates, though neither the dilatation nor contraction are equal. Many gross oversights have arisen, and some dangerous mistakes have been made, by oculists, according to Potterfield, from their not attending to this fundamental law concerning the pupil.

From this expanding and contracting power of the eye, we may learn, why the eye sees best when surrounded with darkness; for the pupil, by dilating, accommodates itself as much as possible to the quantity of light, dilating considerably when the eye is in darkness, and *cæteris paribus*, objects are seen most clearly when the pupil is most dilated; besides, when the eye is in the dark, the picture on the retina is neither confused nor disturbed by adventitious rays; hence those who are in a very bright light, when they want to distinguish accurately a distant object, either depress the eyebrows, or apply the hand to the forehead: hence also a person, by placing himself in the dark, and employing a long tube, will form a species of telescope, producing a greater effect than might at first be conceived: it was on this principle that the ancients used a deep pit, in order to see the stars in the day-time. From hence we also learn, why a person from within a chamber can perceive the objects that are without, while those that are out of doors cannot see the objects that are within: for when we are out of doors, the pupil is contracted, and only a small portion of the light that is reflected from the objects within the chamber, can pass to the retina; while on the contrary, those within have the pupil more dilated, and the objects that are without are also more strongly illuminated; besides which, their view of objects is not much obstructed by the reflection of the window-glass.

* This is what Potterfield and some others say; but from other experiments, the pupil is never so contracted as in the case of going suddenly from a faint to a bright light: the contraction is instantaneous. The effects, therefore, spoken of above, must be referred to the different states of the sensibility of the retina.

It is surprising how far the eye can accommodate itself to darkness, and make the best of a gloomy situation. When first taken from the light, and brought into a dark room, all things disappear; or if any thing is seen, it is only the remaining radiations that still continue in the eye; but after a very little time, the eye takes advantage of the smallest ray, which is confirmed by the following curious account, related by Mr. Boyle. In the time of Charles the first, there was a gentleman, who, sharing in his worthy master's misfortunes, was forced abroad; at Madrid, in attempting to do his king a signal service, he failed; in consequence of this, he was confined in a dark and dismal dungeon, into which the light never entered, and into which there was no opening but by a hole at the top, down which the keeper put his provisions, presently closing it again. The unfortunate loyalist continued for some weeks in this dark dungeon, quite disconsolate; but, at last, began to think he saw some glimmering of light: this dawn of light increased from time to time, so that he could not only discover the parts of his bed, and such other large objects, but, at length, he could perceive the mice that frequented his dungeon, to eat the crumbs that fell upon the ground. When set at liberty, he could not, for some days, venture to leave his cell, lest the brightness of the light should blind him; but was obliged to accustom his eyes, by slow and gradual degrees, to the light of the day.

Of imperfect Sight

There is no branch of science, of which it is more important that a general knowledge should be diffused, than that part which treats of the various imperfections of sight, and the remedies for them. To relieve an organ which is the source of the most refined pleasure, is certainly a desirable object: to enable those who are in want of assistance, to determine whether spectacles will be advantageous or detrimental, and what kind will best suit their sight; and so instruct those who already use glasses, that they may discover whether those they have chosen are adapted to the imperfection of their sight, or are such as will increase their complaint, and weaken their eyes, are subjects worthy the consideration of every individual, and constitute the principal business of the remainder of this work: to this end we shall, in the first place, explain what we mean by an imperfection of sight.

We here understand by imperfect sight, an absolute or relative debility of it, without any opacity, either in the cornea or other internal parts of the eye, and without any disease of the retina or optic nerve.

The sight is relatively imperfect, when we cannot see an object distinctly in a common light, and at all the usual distances at which it is observed by an eye in a perfect state.

In this sense, both the long and short-sighted are said to have an imperfect sight. The short-sighted see distant objects confusedly, those that are near at hand distinctly; their sight is therefore defective with respect to distant objects: on the other hand, the long-sighted see distant objects distinctly, near objects confusedly.

An imperfect sight is occasioned by a confusion in the image formed upon the retina; this happens whenever all the rays that proceed from any one point of an object, are not united again in one, but fall on different points of the retina: or whenever several pencils of light, from different points of an object, terminate upon one point of the image. This species of confusion takes place both in long and short-sighted eyes.

An imperfect sight differs from an amaurosis or gutta serena; for in the latter the sight is entirely lost, and the pupil becomes immovable; though if one eye remain sound, the pupil of the blind eye will be moved with the pupil of the sound one; but if the sound eye be shut, the pupil of the blind eye will be destitute of motion.

Of old or long-sighted Eyes.

To detail those circumstances which are, in general, marks of advancing age, and always of partial infirmity, must be ever unpleasant, and would be equally unnecessary, if it were not the mean of lessening the inconveniences attendant on those stages of life.

By the long-sighted, remote objects are seen distinctly, near ones confusedly; and in proportion as this defect increases, the nearer objects become more indistinct, till at length it is found almost impossible to read a common-sized print without assistance. An imperfect and confused image is formed upon the retina, because the rays of light that come from the several points of an object, at an ordinary distance, are not sufficiently refracted, and therefore do not meet upon the retina, but beyond it.

Various are the causes which may occasion this defect; if the convexity of the cornea be lessened, or if either side of the crystalline becomes flatter, this effect will be produced; if the retina be not sufficiently removed from the cornea or crystalline, or if the retina be too near the cornea or crystalline, it will give rise to the same defect, as will also a less refractive power in the pellucid parts of the eye; in like manner, too great a proximity of the objects, will prevent the rays from uniting till they are beyond the retina; but if all these causes concur together, the effect is greater. This defect is, however, in general, attributed to a shrinking of the humours of the eye, which causes the cornea and crystalline to lose their original convexity, and to become flatter; the same cause will bring the retina too near the cornea.

By one or other of these causes, those who were accustomed in their youth to read a common size print, at about twelve or fourteen inches distance from their eyes, are obliged to remove the book to two or three feet before they can see the letters distinctly, and read with comfort. But in proportion as the object is removed from the eye, the image thereof on the retina becomes smaller, and consequently small objects will not always be perceivable at that distance, to which those in this state find it necessary to remove them, in order to attain any degree of distinct vision: the further also the object is removed, the less light will enter the eye, and the image will, of course, be fainter.

Hence, those who are long-sighted require more light to enable them to read, than they did while their eyes were in their perfect state; and this not only because they are obliged to remove the book to a greater distance, but because the pupil of their eye is smaller, and therefore a greater intensity of light is necessary to produce a sufficient impression on the retina, and compensate for the defect by a greater splendor and illumination of the object.

Increasing years have a natural tendency to bring on this defect, and earlier among those who have made the least use of their eyes in their youth; but whatever care be taken of the sight, the decays of nature cannot be prevented: the humours of the eye will gradually waste and decay, the refractive coats will become flatter, and the other parts of the eye more rigid

and less pliable; thus the latitude of distinct vision will become contracted: it is also highly probable, that the retina and optic nerve lose a portion of their sensibility.

Though it is in the general course of nature, that this defect should augment with age, yet there are not wanting instances of those who have recovered their sight at an advanced period, and have been able to lay aside their glasses, and read and write with pleasure, without any artificial assistance. Among many causes which may produce this effect, the most probable is, that it generally arises from a decay of the fat in the bottom of the orbit; the pressure in this part ceasing, the eye expands into somewhat of an oval form, and the retina is removed to a due focal distance from the crystalline.

It is a certain and very important fact, that long-sightedness may be acquired; for countrymen, sailors, and those that are habituated to look at remote objects, are generally long-sighted, want spectacles soonest, and use the deepest magnifiers; on the other hand, the far greater part of the short-sighted are to be found among students, and those artists who are daily conversant with small and near objects; every man becoming expert in that kind of vision, which is most useful to him in his particular profession and manner of life: thus the miniature painter, and engraver, see very near objects better than a sailor; but the sailor perceives distant objects better than they do: the eye in both cases endeavouring to preserve that configuration to which it is most accustomed. In the eyes, as well as other parts of the body, the muscles, by constant exercise, are enabled to act with more ease and power, but are enfeebled by disuse; the elastic parts also, if they are kept too long stretched, lose part of their elasticity; while on the other hand, if they be seldom exercised, they grow stiff, and are not easily distended. From the consideration of these facts, we may learn, in a great measure, how to preserve our eyes; by habituating them occasionally to near as well as distant objects, we may maintain them longer in their perfect state, and be able to postpone the use of spectacles for many years; but we may also infer from the same premises, that there is great danger, when the eyes are become long-sighted, of deferring too long the use of spectacles, or using those that magnify too much, as we may by either method so

flatten the eye, as to lose entirely the benefits of naked vision. It may not be improper in this place to remark, that the long-sighted eye is much more liable to be injured by too great a degree of light, than those that are short-sighted.

Objects that appear confused to the long-sighted, will be rendered more distinct, if they view them through a small hole, such as that made by a pin in a card, because it excludes those diverging rays which are the principal source of confusion; but as it, at the same time, intercepts a considerable portion of the light, it is by no means an adequate remedy. The best relief they can obtain is from convex glasses, for by these the rays of light that proceed from the object, are so refracted, as to fall upon the retina, in the same manner as if they issued from a distant point. Spectacles afford two advantages, for they not only render the picture of objects distinct upon the retina, but they also make it strong and lively.

Of Spectacles.

The discovery of optical instruments may be esteemed among the most noble, as well as among the most useful gifts, which the Supreme Artist hath conferred on man. For all admirable as the eye came out of the hands of him who made it, yet he has permitted this organ to be more assisted by human contrivance, than any other of the animal frame, and that not only for the uses and comforts of common life, but for the advancement of natural science; whether by giving form and proportion to the minute parts of bodies, that were imperceptible to the unassisted sight, or by contracting space, and as by magic art, bringing to view the grander objects of the universe, which were rendered invisible by their immense distance from us. * Noble as these inventions are, the discovery of spectacles may still claim the superiority, as being of more universal benefit, and more extensive use. They restore and preserve to us one of the most noble and valuable of our senses; they enable the mechanic to continue his labour, and earn a subsistence by the work of his hand, till the extreme of old age. By their aid the scholar pursues his studies, and recreates his mind with intellectual pleasures, and thus passes away days and years with delight and satisfaction, that might otherwise have been devoured by melancholy, or wasted by idleness.

* Sir John Pringle's Six Discourses.

As spectacles are designed to remedy the defects of sight, it is natural to wish, that the materials of which they are formed should be as perfect as the eye itself; but vain is the wish, for the materials we use, like every thing human, are imperfect, and yet we may deem ourselves happy, to have in glass a substitute so analogous to the humours of the eye, a substance which gives new eyes to decrepid age, and enlarges the views of philosophy. The two principal defects are, small threads or veins in the glass, and minute specks. The threads are most prejudicial to the purposes of vision, because they refract the rays of light irregularly, and thus distort the object, and fatigue the eye; whereas the specks only lessen the quantity of light, and that in a very small degree.

General Rules for the Choice of Spectacles.

The most general, and perhaps the best rule that can be given, to those who are in want of assistance from glasses, in order so to choose their spectacles, that they may suit the state of their eyes, is to prefer those which shew objects nearest their natural state, neither enlarged nor diminished, the glasses being near the eye, and that give a blackness and distinctness to the letters of a book, neither straining the eye, nor causing any unnatural exertion of the pupil.

For no spectacles can be said to be properly accommodated to the eyes, which do not procure them ease and rest; if they fatigue the eyes, we may safely conclude, either that we have no occasion for them, or that they are ill made, or not proportioned to our sight.

Though, in the choice of spectacles, every one must finally determine for himself, which are the glasses through which he obtains the most distinct vision; yet some confidence should be placed in the judgment of the artist, of whom they are purchased, and some attention paid to his directions. By trying many spectacles the eye is fatigued, as the pupil varies in size with every different glass, and the eye endeavours to accommodate itself to every change that is produced. Hence, the purchaser often fixes upon a pair of spectacles, not the best adapted to his sight, but those which seem to relieve him most, while his eyes are in a forced and unnatural state; and consequently, when he gets home, and they are returned to their natural state, he finds what he had chosen, fatiguing and injurious to his sight.

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Of Preservers, and Rules for the Preservation of the Sight.

Though it may be impossible to prevent the absolute decay of sight, whether arising from age, partial disease, or illness, yet by prudence and good management, it's natural failure may certainly be retarded, and the general habit of the eyes strengthened, which good purposes will be promoted by a proper attention to the following maxims.

1. Never to sit for any length of time in absolute gloom, or exposed to a blaze of light. The reasons on which this rule is founded, prove the impropriety of going hastily from one extreme to the other, whether of darkness or of light, and shew us, that a southern aspect is improper for those whose sight is weak and tender.

2. To avoid reading a small print.

3. Not to read in the dusk; nor, if the eyes be disordered, by candle-light. Happy those who learn this lesson betimes, and begin to preserve their sight, before they are reminded by pain, of the necessity of sparing them; the frivolous attention to a quarter of an hour of the evening, has cost numbers the perfect and comfortable use of their eyes for many years: the mischief is effected imperceptibly, the consequences are inevitable.

4. The eye should not be permitted to dwell on glaring objects, more particularly on first waking in a morning; the sun should not of course be suffered to shine in the room at that time, and a moderate quantity of light only be admitted. It is easy to see, that for the same reasons, the furniture of a bed should be neither altogether of a white or red colour; indeed, those whose eyes are weak, would find considerable advantage in having green for the furniture of their bed-chamber. Nature confirms the propriety of the advice given in this rule: for the light of the day comes on by slow degrees, and green is the universal colour she presents to our eyes.

5. The long-sighted should accustom themselves to read with rather less light, and somewhat nearer to the eye than what they naturally like; while those that are short-sighted, should rather use themselves to read with the book as far off as possible. By this means, both would improve and strengthen their sight; while a contrary course will increase it's natural imperfections.

There is nothing which preserves the sight longer, than always using, both in reading and writing, that moderate degree of light which is best suited to the eye; too little strains them, too great a quantity dazzles and confounds them. The eyes are less hurt by the want of light, than by the excess of it; too little light never does any harm, unless they are strained by efforts to see objects, to which the degree of light is inadequate; but too great a quantity has, by it's own power, destroyed the sight. Thus many have brought on themselves a cataract, by frequently looking at the sun, or a fire; others have lost their sight, by being brought too suddenly from an extreme of darkness into the blaze of day. How dangerous the looking upon bright luminous objects is to the sight, is evident from it's effects in those countries which are covered the greater part of the year with snow, where blindness is exceeding frequent, and where the traveller is obliged to cover his eyes with crape, to prevent the dangerous, and often sudden effects of too much light: even the untutored savage tries to avoid the danger, by framing a little wooden case for his eyes, with only two narrow slits: A momentary gaze at the sun, will, for a time, unfit the eyes for vision, and render them insensible to impressions of a milder nature.

The following cases from a small tract on the "*Fabric of the Eye*," are so applicable to the present article, as to want no apology for their insertion here; though if any were necessary, the use they will probably be of to those whose complaints arise from the same or similar causes, would, I presume, be more than sufficient.

"A lady from the country, coming to reside in St. James's-square, was afflicted with a pain in her eye, and a decay of sight. She could not look upon the stones, when the sun shone upon them, without great pain. This, which she thought was one of the symptoms of her disorder, was the real cause of it. Her eyes, which had been accustomed to the verdure of the country, and the green of the pasture grounds before her house, could not bear the violent and unnatural glare of light reflected from the stones; she was advised to place a number of small orange trees in the windows, so that their tops might hide the pavement, and be in a line with the grass. She recovered by this simple change in the light, without the assistance of any medicine; though her eyes were before on the verge of little less than blindness."

"A gentleman of the law had his lodgings in Pall-mall, on the north-side, his front windows were exposed to the full noon sun, while the back room, having no opening, but into a small close yard, surrounded with high walls, was very dark; he wrote in the back room, and used to come from that into the front to breakfast, &c. his sight grew weak, and he had a constant pain in the balls of his eyes; he tried visual glasses, and spoke with oculists, equally in vain. Being soon convinced, that the coming suddenly, out of his dusky study, into the full blaze of sun-shine, and that very often in the day, had been the real cause of his disorder; he took new lodgings, by which, and forbearing to write by candle-light, he was very soon cured."

Blindness, or at least miserable weaknesses of sight, are often brought on by these unsuspected causes. Those who have weak eyes, should therefore be particularly attentive to such circumstances, since prevention is easy, but the cure may be difficult, and sometimes impracticable.

I hope I shall not be thought to have stepped improperly out of the line of my profession, in recommending the following remedy, when a decay or weakness of sight comes on earlier than might reasonably be expected, and without any disease, or other apparent cause; if it does not answer the purpose, no ill will attend the use of it. Put two ounces of rosemary leaves into a bottle, with a pint of brandy, shake it once or twice a day; let this stand three days, then strain it off; mix a tea spoonful of the clear tincture with four tea spoonfuls of warm water, and wash the inside of the eye with it every night, moving about the eye-lids, that some of it may get perfectly in between the lid and the eye. By degrees put less and less water to the tincture, till at length a tea spoonful of each may be mixed for use.

Whatsoever care, however, be taken, and though every precaution be attended to with scrupulous exactness; yet as we advance in years, the powers of our frame gradually decay, an effect which is generally first perceived in the organs of vision.

Age is, however, by no means an absolute criterion, by which we can decide upon the sight, nor will it prove the necessity of wearing spectacles. For, on the one hand, there are many whose sight is preserved in all it's

vigour, to an advanced old age; while, on the other, it may be impaired in youth by a variety of causes, or be vitiated by internal maladies; nor is the defect either the same in different persons of the same age, or in the same person at different ages; in some the failure is natural, in others it is acquired.

From whatever causes this decay arises, an attentive consideration of the following rules, will enable every one to judge for himself, when his sight may be assisted or preserved by the use of spectacles.

1. When we are obliged to remove small objects to a considerable distance from the eye, in order to see them distinctly.
2. If we find it necessary to get more light than formerly; as for instance, to place the candle between the eye and the object.
3. If on looking at, and attentively considering a near object, it becomes confused, and appears to have a kind of mist before it.
4. When the letters of a book run one into the other, and hence appear double and treble.
5. If the eyes are so fatigued by a little exercise, that we are obliged to shut them from time to time, and relieve them by looking at different objects.

When all these circumstances concur, or any of them separately take place, it will be necessary to seek assistance from glasses, which will now ease the eyes, and in some degree check their tendency to grow flatter; whereas if they be not assisted in time, the flatness will be considerably increased, and the eyes be weakened by the efforts they are compelled to exert.

We are now able to decide upon a very important question, and say how far spectacles may be said to be *preservers of the sight*. It is plain they can only be recommended as such, to those whose eyes are beginning to fail; and it would be as absurd, to advise the use of spectacles to those who feel none of the foregoing inconveniences, as it would be for a man in health to use crutches to save his legs. But those who feel those inconveniences, should immediately take to spectacles, which, by enabling them to see objects nearer, and by facilitating the union of the rays of light on the retina, will support and preserve the sight.

When the eye sensibly flattens, all delay is dangerous; and the longer those who feel the want of assistance, defer the use of spectacles, the more they will increase the failure of the eye; there are too many who procrastinate the use of them, till at last they are obliged to use glasses of ten or twelve inches focus, instead of those of 36 or 40, which would otherwise have suited them; thus preferring a real evil, to avoid one that is imaginary. Mr. Thomin mentions several deplorable cases of this kind, particularly one of a lady, who, through false shame, had abstained from wearing spectacles so long a time, that at last it was impossible to suit her, but with those adapted to eyes that have been couched. Whereas the instances are numerous of those who, by using glasses of a long focus at the first approaches of long-sightedness, have brought back their eyes to their natural sight, and been able to lay aside their spectacles for years.

These considerations point out clearly the advantages that may be obtained by a proper choice of spectacles on first wearing them, and the importance of making such a choice; as the eye will endeavour to conform itself to any improper focus, and thus be brought into a state of extreme age, at a much earlier period than would have happened, had they been suited with judgment. There are very few opticians but what must have seen instances of those, who, by habituating their eyes to too short a focus, or too great a magnifying power, have so injured those tender organs, as to deprive them of future assistance from glasses. This frequently happens to those who purchase their spectacles of hawkers and pedlars, men equally ignorant of the science of optics, and the fabric of the eye.

Let it, therefore, be carefully remembered, that magnifying power is not the point that is most to be considered in the choice of spectacles, but their conformity to our sight, their enabling us to see distinctly, and with ease, at the distance we were accustomed to read or work, before the use of spectacles became necessary: or, in other words, glasses should so alter the disposition of the rays, at their entrance into the eyes, as will be most suitable to procure distinct vision at a proper distance; an end of the highest import, as in this respect it places the aged nearly on a level with the young, and enables him to read a common print with ease, at a period when, without assistance, he could hardly distinguish one letter from another.

In proportion as the eye flattens, glasses of greater convexity are to be used; but still we should be careful not to go too far: for if they magnify too much, they will fatigue the eye. The most certain criterion of their being too old for the actual state of the sight, is our being obliged to bring the objects we look at through them, nearer the eye than the common distance of distinct vision. All glasses that cause us to depart much on either side from the limits of distinct vision, may be considered as ill adapted, and prejudicial to the sight.

Those who are careful in following a regular gradation, may preserve their eyes to the latest period of old age, and even then be able to enjoy the comforts and pleasures that arise from distinct vision. Do not, therefore, precipitate these changes, lest you should absorb too soon the resources of art, and not be able to find spectacles of sufficient power to relieve the eye. One precaution more is necessary: by no means put on any spectacles but your own; for taking up, and wearing glasses different from those to which your eye is accommodated, has the same ill effect as trying a variety at an optician's shop; this variety fatigues and disturbs the sight; all irregularity is injurious, and much of the preservation of the sight depends upon keeping it uniform, as well with regard to the glasses, as the degrees of light.

There are many who find the effect of candle-light so different from the purer light of day, that they are obliged to use spectacles by night, though they can do very well without them in the day. These, when the eye has become more flat, will find it adviseable to have two pair of spectacles, one to use by day, the other, magnifying somewhat more, appropriated for the night; by this means, nearly the same quantity of light may be brought to act upon the retina at one time as the other; thus the eyes will be less fatigued, and longer maintain their natural vigour.

Of Visual Spectacles.

The natural desire of men in trade to increase their business, and extend their fame, has in many instances been the origin of alterations and inventions, injurious to science, and detrimental to the public. It is a desire, to which all in trade are, from their situation, exposed; and from which, it may be presumed, no one is exempt.

To this desire we may, with propriety, impute the invention of visual spectacles; and as pretences are seldom wanting to justify that which interest adopts, the inventor endeavoured, by specious reasons, to attract the attention of those who were not to be captivated by mere novelty. But the good sense of the world, which always, in the long run, justly appreciates the value of every invention, now leaves visual spectacles to the neglect they merit; they are worn by few, but those who, from long habit, have accustomed their eyes to these pernicious shades.

Among the reasons adduced by the inventor, the following is that upon which the greatest stress was laid, namely, that as in telescopes, microscopes, &c. we are obliged, by proper apertures, to cut off those extraneous rays which tend to render the image confused; so, in the same manner, the quantity of light should be adjusted in spectacles. To this it was then answered, that the cases were by no means analogous, and if they were, the reason alledged would operate against the use of visual glasses; for as all lenses bear an aperture proportional to their focal length, a lens of five inches focus, which is one of the shortest in general use, would bear a much larger aperture than the diameter of any spectacle eye; but there was surely no need of apertures to glasses, applied close to the eye, whose pupil is formed by nature to adapt itself to every degree of light; and we should in all cases, leave the eyes as much as possible to their own exertions and uniform mode of acting. Considered as a shade or screen, the horn rims of the visual glasses are imperfect and detrimental, they are also inconvenient in use; for if the line to be read is long, the head must be in continual motion, to see the words, which are obstructed by the opaque rim; to these, and many other reasons which might be adduced, we may add the proofs derived from experience and observation; by these I am fully convinced, that they are injurious to the eye, and that in general those who wear them, use glasses of a shorter focus than those who wear the common sort.

If from the weakness of the eye a shade be necessary, let it be such a one as is pointed out by nature: she teaches us, that those whose eyes are deep set, have the clearest and strongest sight; and that whenever we find the light too strong we pull down our eye-brows, and if this be not

sufficient, put our hand over our eyes; by this we are instructed, that the best form for a shade is one fitted to the forehead, and projecting from it 2 or 3 inches.

It may not be improper in this place to say a word or two respecting shades or screens for candles. I am clearly of opinion, that all opaque shades are detrimental to the eye, as well from the very irregular reflections of the light, from the paint on the inside of them, as from the vast contrast into which the eye is thrown, when it removes from the reflected light, that is, from an extreme of brightness to gloominess and obscurity. In the place of these, I would recommend a conical shade of white paper, moderately thick; this will throw a strong steady light down on the book, &c. it will preserve the eye from the luminous brightness and glare of the candle, and not darken the room too much. Here I cannot refrain from observing, that the clear white light of Argand's lamps must be very prejudicial to the sight; there are purposes to which they may be applied with advantage, but then it should be where their light is modified before it reaches the eye.

Of Spectacles with coloured Glasses.

It may be more difficult to decide upon the merit of spectacles with coloured glass, than of those with visuals; yet upon the whole, there is reason to think, that they are rather of dis-service than of any use to the eye, and that the grounds upon which it has been supposed that they would be advantageous to the sight, are weak and fallacious.

Green glasses have been recommended on two accounts, first, because green is universally allowed to be one of the pleasantest colours we look at, and is found to strengthen, comfort, and preserve the sight; secondly, as they are supposed to weaken the impression of the rays of light on the retina, and therefore to be well adapted to those whose eyes are weak and tender.

To the first reason, it may be sufficient to answer, that though green is a pleasant colour to look at, it is by no means so to look through; for all objects, when viewed through green glass, appear of a muddy yellow, tinged by a gloomy green; they are, however, not only unpleasant,

but there are circumstances attending the use of them, which make it highly probable, that they are prejudicial to the sight, and have not the tendency which is generally attributed to them, of lessening the action of the rays of light on the eye.

After looking at the sun for a short time, shut your eyes, and you will, for some time after they have been shut, continue to see his image; but it's brightness will gradually diminish, assuming, successively, colours less and less bright and lively, being first red, afterwards yellow, then green, blue, and lastly, violet; now these colours are attributed to the violent agitation excited in the retina, by the rays of light; the re-action and vibrations produce the sensation of colour, the strongest those of red, the weaker those of yellow, &c. Something very similar to this happens to most people, on their first wearing green glasses, for on taking them off, they generally find white objects tinged with red; a clear and sufficient proof, that they are not favourable to the eye.

Further, unless they are continually wore, the contrast between the object seen through them, and seen without them, must be disadvantageous in it's effects; as contrary to that uniformity, which we have already observed, to be so necessary to the preservation of the eyes.

But there is a still greater inconvenience; the eye, by constant use, so habituates itself to them, as not to be able to see with ease in spectacles of another colour: now as the eye grows flatter, it wants glasses of a greater convexity; but as the convexity increases, the green glasses become more opaque, and thus less fit for vision, affording least assistance when the eye wants it most.

Of Reading-Glasses.

Though the effects of time are the certain and inevitable portion of all, who live to an advanced age, and are neither to be retarded by riches, nor prevented by wisdom; yet such are the weaknesses of the human mind, and such the partialities of self-love, that we all endeavour to conceal, from ourselves and others, the approaches of age; and no one likes to appear as hastening to that bourne from which none have returned.

These propensities give rise to a variety of artifices, by which each individual endeavours to hide from himself and others, what no artifice can conceal, and which every one can discover, in all but himself; but then, these endeavours often contribute to hasten the evils they are meant to conceal. Opticians have daily experience of the truth of these observations, and they are in no instance more fully verified, than in the preference given by many to reading-glasses, (under whatever pretext it may be covered,) merely because they think, that the decay of their sight, and their advances in age, are less conspicuous by using a reading-glass than spectacles.

It is evident, that the axes of the eyes ought not in any case to be strained, but that they should be left at liberty, to follow the direction they receive from the muscles of the eye; but this is not the case when a reading-glass is used; for the eyes, in endeavouring to see by it, are considerably strained, and in a short time much fatigued: but there is another objection to the use of reading-glasses, which arises from the unsteadiness of the hand, and the motion of the head, which occasion a perpetual motion of the glasses, for the eye endeavours to conform itself to each change, and this tender organ is thereby kept in continual agitation: to these evils we may add, the dazzling glare and irregular reflection from the surface of the glass, which so weaken the eyes, that those who accustom themselves to a reading-glass, are in a short time obliged to take to spectacles, and to use them much older than they otherwise would have done.

To this it may be added, that spectacles are preferable, not only as more conformable to the nature and action of the eye, but they are also more convenient; the space between the face and the object is left open and free, and they are moved insensibly by the natural motion of the head; they also shew objects more clear and more distinct than a broad lens, because their glasses are thinner, and placed exactly before each eye.

To obviate some of these inconveniences, my father contrived a kind of substitute for spectacles, which are convenient for looking at any occasional object, and not injurious to the eyes; this kind is represented

at fig. 8. In these both eyes are used at once, without any effort; by being held near the eye, the irregular reflections are avoided, and they are at the same time rendered steady, by a slight pressure of the middle bar on the nose.

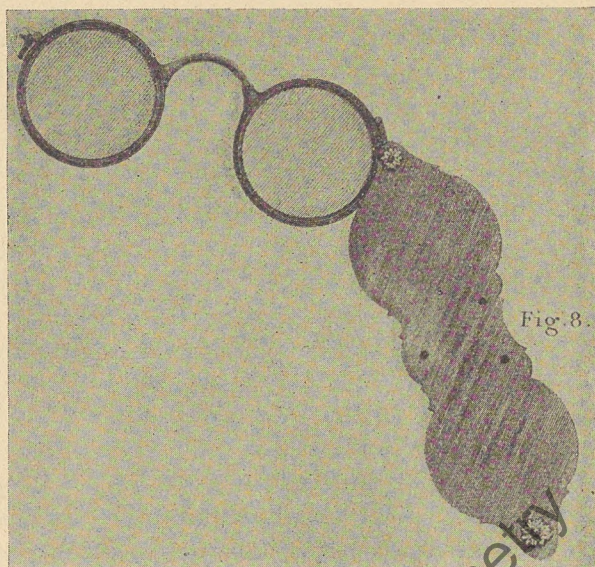


Fig. 8.

To suit a given Eye with proper Spectacles, or to enable a given Eye to see distinctly at a certain Distance.

For this purpose, a rule is delivered by optical writers, which, though it is good in theory, is liable to several exceptions in practice, particularly as by exactly adhering to it, they would generally choose glasses of too great a magnifying power; but as notwithstanding this defect, the data it requires may give useful information to the optician, for furnishing glasses to those who live in the country, we shall insert it here.

Rule.

To find a convex lens suited to a long-sighted eye, multiply the distance at which the person sees distinctly, by the distance at which it is desirable he should see with the spectacles, and divide the product, by the difference between the two aforesaid distances, the result is the focus required.

Those who, using spectacles, live at a distance from town, and think those they have are not accommodated to their sight, may receive information whether they can be better suited or not, by sending any skilful optician the focus of the glasses in their spectacles, and the distance at which with them they can read a small print.

To find the focus of a convex lens, of spectacle eye, first by the sun's image, place the lens, so that it's axis may be toward the sun; then holding a paper behind it, the burning point or where the sun's image is smallest, and where the limb is most distinct, is the focus of the lens, and the distance from this point to the lens is the distance required.

Or, secondly, fix a piece of paper on the side of a room, exactly facing a window, and remove the lens from this, till the images of the most distant objects out of doors are distinct, then the distance between the lens and the paper is the required focal length: the images will be brighter the less the quantity of light is admitted into the room, except what is directly opposed to the lens.

The foregoing methods are sufficiently accurate for common spectacles and reading-glasses, but not for lenses of a long focus.

Of Couched Eyes.

With the diseases of the eye, this small essay has no concern; they have been already well and ably considered by professional men; and it is scarce necessary to observe, that in anatomical knowledge, and in the practical operations of surgery, England now claims a just pre-eminence over other nations.

But among the various diseases of this organ, there is one in which, after the surgeon has quitted the patient, glasses are necessary, to give effect to the operation, and a comfortable sight of objects to the person relieved. This disease is the cataract, a disorder affecting the crystalline humour of the eye; when the opacity is confirmed, this humour becomes so opaque, as scarcely to admit any rays of light, and prevents their producing their ordinary effects, and consequently no image of any object is formed, though the retina, and other organs of sight, are in perfect order. There is no disorder more deplorable in it's nature and consequences; destructive of the sight, often beyond the reach of remedy: the hand of the operator is the only hope, and his efforts are sometimes unsuccessful.

The cause of this disorder is seldom known. Sometimes it has been thought to be brought on by frequent inspection of the sun, and sometimes by looking too long and too often at a bright fire. In early stages of the disease it has been thought to be removed by medicine*. Of the various remedies that have been used for this purpose, the electrical stream is supposed by many to be the best, on account of it's powerful discutient properties.

* Baron de Wenzel, in his Treatise on the Cataract, denies that any medicine has power to dissipate the opaque crystalline. Mr. Ware, in his translation of this work, assents to the truth of the Baron's observation, so far as is at present known; but adds, that many cases have occurred, under his own inspection, which prove that the powers of nature are often sufficient for this purpose. Those opacities in particular which are produced by external violence, he has repeatedly seen dissipated in a short space of time, when no other parts of the eye have been hurt; and in general, in cases of this description, the crystalline humour has been dissolved; which has been demonstrated, by the benefit the patient has afterwards derived from adopting the use of deeply convex glasses. Mr. Ware adds, that instances are not wanting, in which cataracts, which were formed without any violence, have been suddenly dissipated, in consequence of an accidental blow on the eye. For these reasons he entertains a hope, that means may hereafter be discovered, by which an opaque crystalline may be rendered transparent, without the performance of any operation whatever. The remedies which have appeared to Mr. Ware more effectual than others, in these cases, have been the application to the eye itself of one or two drops of æther, once or twice in the course of the day, and the occasional rubbing of the eye over the lid, with the point of the finger, first moistened with a weak volatile or mercurial liniment. See Ware's translation of Wenzel's Treatise on the Cataract, page 13.

The assistance the eye receives from the surgeon is either by a depression of the crystalline below the pupil, or extracting the cataract. But as the density of the vitreous humour, which supplies the place of the crystalline, is less, the rays of light will be less refracted, and not meet at the retina, but at some distance behind it; the sight will therefore be imperfect, except the eye be assisted with a proper convex glass. There is a circumstance attending couched eyes, which fully evinces that the change made in our eyes, to accommodate them to the distances of objects, must be principally attributed to the crystalline humour; namely, that one focus is seldom sufficient to enable those who have undergone this operation, to see objects at different distances. They generally require two pair of spectacles, one for near, the other for more distant objects. The foci that are used lie between 6 and $1\frac{1}{2}$ inches.

It is not advisable to use glasses too soon after the operation; for while the eyes are in a debilitated state, all exertions are not only improper, but also very prejudicial.

Of the Short-sighted.

In this defect of the eyes, the images of objects at an ordinary distance unite before they arrive at the retina, and consequently the images formed thereon are confused and indistinct. This effect is produced either by too great a convexity in the cornea and crystalline, or too great a refractive power in the humours of the eye; or the retina may be placed too far; or it may arise from a concurrence of all these circumstances.

Those who are short-sighted can distinguish smaller objects, and see clearly a given small object with less light than other people; the reason is evident, for the nearer the object is, the more light enters the pupil; being also more dense, it's action is more powerful on the retina; hence the short-sighted can read a small print by moon-shine, or in the twilight, when a common eye can scarce distinguish one letter from another.

In a strong light they can see a little farther than they do when it is weak; the strength of the light causes the pupil of their eyes to contract, and thus removes in some degree the indistinctness of the objects. Upon the same principle we may account for the short-sighted so often partly

shutting their eyelids, from whence they were formerly denominated *myopes*; by this means, they confine the bases of the pencils of rays which issue from the points of an object, and thus contract the circle of dissipation, and lessen the indistinctness of vision: hence they also see objects more distinctly through a small hole, as that made by a pin in a card.

It is a common observation, that the short-sighted do in general prefer a small print to a large one, and that they usually write a small hand; for by the proximity the letters are magnified, and, being small, they take in a greater number at one view; they hold the book they are reading in generally inclined to one side, in order to attain a greater degree of illumination. As they can only see distinctly objects that are near, they are obliged, by a strong effort of the mind, to cause the axes of the eyes to converge; this effort being painful, forces them often to turn away one of their eyes, which producing double vision, they are obliged to shut it. When they hold a book directly before their eyes, the picture will fall upon the middle of the retina, but if they hold it obliquely it will fall upon the side of the retina; now the middle of the retina is further from the fore part of the eye than the side of it is. Therefore though the picture be so near to the fore part of the eye as to be confused if it fall upon the middle, it may be distinct when it falls upon the side.

As those who are very short-sighted do not perceive the motion of the eyes and features, they seldom look attentively at those with whom they are conversing: it is from this circumstance that Pliny terms the prominent-eyed *hebetiores*; not that this defect in sight impairs genius, or lessens the powers of the mind; but as it deprives them of the rapid communications that are made by the eye, it apparently lessens that vivacity of conception, which always accompanies a vigorous mind.

Happily for the short-sighted, the principal inconveniences of their sight may be remedied by the use of concave glasses; by their assistance, those whose sphere of distinct vision scarce extended beyond their arm, are enabled to distinguish, very satisfactorily, objects at a considerable distance; the concave lens produces distinct vision, by causing the rays to diverge more, and unite at the retina, instead of meeting before they reach the bottom of the eye.

In the choice of glasses for the short-sighted, no rules can be laid down; it is a defect that has no connection with age, no stated progression that can be a foundation to guide the optician, or lead him to recommend one glass in preference to another; the whole must depend on the observation of the short-sighted themselves, who, by trying glasses of different degrees of concavity, will soon find out that whose effects are most advantageous, producing distinct vision at different distances.

If the short-sighted person is so far removed from an optician, as not to have an opportunity of trying a variety of lenses, he may be nearly suited, by sending to him the greatest distance at which, with his naked eye, he can see distinctly; he will, by the following rule, be enabled to suit him with tolerable exactness.

Multiply the distance at which the short-sighted person sees distinctly with his naked eye, by the distance at which it is required he should see distinctly by a concave glass, and divide the product by the difference between the aforesaid distances: if the required distance be very remote, the glasses must be of that radius at which they see distinctly with their naked eyes.

The benefit the short-sighted receive from concave glasses, is not so great as the long-sighted find by a convex lens; for an object is not only magnified, but the eye receives also a larger pencil of light from each visible point, because the rays enter less diverging; whereas the concave not only diminishes the object in size, but it lessens also the quantity of light, as it renders the rays more diverging; consequently the short-sighted do not see remote objects, unless they are very large and bright, so well through a concave lens as theory promises: for the chief impediment to a distinct view of remote objects, is their want of light and magnitude, but both of these a concave lens increases.

It is generally supposed, that the short-sighted become less so as they advance in years, as the natural shrinking and decay in the humours of the eye lessen it's convexity, and thus adapt it better for viewing of distant objects: but among the great number of short-sighted that I have accommodated with glasses, I have ever found the reverse of this theory to be true, and the eyes of the myopes never required glasses less concave, but generally more concave as they grew older, to enable them to see at the same distance.

Further, the effects of habit, which are in most cases very powerful, but peculiarly so in the affections of the eye, have a natural tendency to increase the defect of the myopes, for by frequently looking close to objects, in order to see them distinctly, they would make themselves near-sighted, though their eyes were naturally the reverse; hence we often find, that watch-makers, engravers, and studious persons, often bring on this defect. By reading or working at as great a distance as possible, and often looking at remote objects, the degree of short-sightedness may be much lessened. As children in general read much nearer than grown persons, if they are suffered to indulge this propensity, they become naturally short-sighted.

I have found it necessary, in some instances, to give convex glasses to the short-sighted, when very far advanced in age, not because their eyes were grown less convex, but to give them more light, and counteract an extreme contraction of the pupil.

Great as are the disadvantages of the short-sighted, they are less, perhaps, with respect to distant objects, than is generally imagined; they see the brighter stars and planets, nearly as well as other people. They are prevented indeed from distinguishing beyond a certain small distance, the small parts of an object which are very visible to another; thus they cannot distinguish the features of a face across a room, and as objects are generally discriminated by their minuter parts, their disadvantage in viewing objects at a moderate distance is very evident. But though such a person cannot discern the minutiae of objects, unless they are very large and very near him; yet he can perceive any object in the gross, at a considerable distance, if it be not too small: thus he may perceive a man at the distance of several paces, but must advance within one or two, before he can determine who he is, or call him by his name; he will see a large tree much further, and from experience in such cases, will perceive, that a large obscure object at a great distance is an house, to the surprise of his friends who are acquainted with the nature of his sight. On these principles, we may easily account for the apparent paradox of the pur-blind, or those who can scarcely see a small object at arm's length yet discovering those that are very remote.

Of a Crepuscular or Twilight Blindness.

Those that are afflicted with this complaint, have their sight dull and confused in the evening and morning, discerning objects very imperfectly at the same time and place: while those who are blessed with perfect vision, see them distinctly.

Many years ago, this disorder was epidemical in the neighbourhood of Montpellier, especially in towns, contiguous to a river, and among the soldiers doing duty as sentinels, exposed to the damps and fogs of the night season; and it was judged to proceed from a superfluous serum in the mass of blood, which affected and relaxed the organs of vision; the pupil of the eye was much dilated, and the sensibility of the retina lessened.

Boerhaave mentions a variety of this disorder, which arose from an immoveable structure of the pupil; it did not, like the other, give way to medicine; it is probable, that in both cases, electricity would be of great use.

Of Meridian Blindness.

Those who are afflicted with this disorder, can discern objects in the night, but are unable to distinguish them in the day-time.

Boerhaave enumerates two varieties of this disorder. The first proceeds from an opaque round spot, or partial cataract in the middle of the crystalline, exactly behind, but somewhat smaller than the pupil; during the day, the pupil is so contracted as to admit no rays of light, but what fall upon the opaque spot, which, therefore, prevents the formation of any image upon the retina; but in the evening, the pupil is so dilated, as to permit such a quantity of light as will answer the purposes of vision.

This variety may be removed by the electric fluid; or if that does not succeed, by the couching needle.

The second variety arises from so extreme a sensibility of the retina, that it entirely closes the pupil of the eye; this species generally yields to antiphlogistic remedies.

Of an absolute Dulness of Sight.

This kind of sight has been generally confounded with long-sightedness, but has lately been ranked, by some anatomical writers, under a distinct head.

Both the short and long-sighted, in certain positions, and at certain distances, see objects distinctly, and their sight is not confused but relatively, with respect to other distances, positions, and times; but in the affection of the eye now under consideration, there is an absolute dulness of sight, in all places, at all times, and in all situations.

It seems to depend on a want of sensibility in the retina, and happens more especially to those who have abused their eyes: it is a disease to which, by common people, a variety of causes are assigned.

The principal symptoms are frequent variations in the boundaries of distinct vision; objects, when attentively considered, appear confused, the characters of books seem to be doubled, moved, and decussated; the eyes being soon fatigued, they are frequently obliged to rub and shut them, and the pupil is scarcely moveable, even on a sudden transition from darkness to light.

Various are the remedies prescribed by oculists for this disorder, some praising spirituous resolvents, while others extol cold water; but all agree in recommending the use of spectacles, with double convex glasses; for as by these more rays of light are collected, and a stronger impression made on the retina, a considerable degree of distinctness is promoted.

Electricity has been recommended with success, the eye has been in part restored, and the pupil recovered it's power of contracting and dilating.*

* The following case, which fully evinces the powers of electricity in diseases of the eye, was communicated to me by my very ingenious friend, John Birch, Esq. surgeon of St. Thomas's hospital.

In the year 1786, Ann Bone, aged 57, was admitted into St. Thomas's hospital, under the care of Mr. Chandler, totally blind. After the usual remedies had been unsuccessfully tried, she was sent to the electrical chamber, where Mr. Whitelocke, now surgeon at Ramsbury, had the care of the machine, under the direction of Mr. Birch. The shocks were passed through the globe of the right eye, and the sight of that eye was recovered in one week's experiment. The woman was desirous of leaving the hospital, content with the recovery of the sight of one eye, and fearful of the pain she experienced from the shocks; but a report of the case being made to the surgeons, Mr. Birch directed the electric fluid from a wooden point only, to be poured into the other eye, which perfectly restored the sight of it, though not in so short a time. At the end of the month she was discharged from the hospital, perfectly cured, able to read, work, and tell the time by a watch.

Several similar cases have since happened, with which, perhaps, the public may, in time, be made acquainted; though most of them are cases of the gutta serena, the cataract not having been found to yield to electricity. See a remarkable case of the gutta serena, accompanied with a paralysis of the eye-lids, which was perfectly cured by an electric application in three days, annexed to Mr. Ware's Remarks on the ophthalmia, psorophthalmia, and purulent eye, page 151, second edition, printed for Dilly, 1787.

Among the lesser maladies of the eyes, the most common is a redundancy of water, or of a watery humour, which disturbs and impairs the sight. When the eye is full of water, letters appear confused, and no small object is seen distinctly. In this case it is usual to have recourse to spectacles; but the author of an excellent little tract on the fabric of the eyes, says, that in this disorder it is the glass, not the form, that is necessary; and that when it is the extreme moisture of the ball of the eye alone, which makes objects appear confused, they will be rendered distinct, by placing a piece of thick clear glass between the eye and the object: he, therefore, advises the use of a pair of spectacles, of plain thick coach-window glass, without any convexity: the use of these will forward the cure, which will soon be effected by an application of the proper remedies, care being taken at the same time to avoid extremes of light.

Of Squinting.

I hesitated long, whether I should say any thing concerning this affection of the eyes, but was at last determined, by considering, that this essay might pass into many hands, who would probably never see those philosophical and medical treatises, in which this subject has been particularly handled; and that I might, therefore, be a mean of communicating useful knowledge to those whom it would otherwise never reach.

It must, however, be confessed, that after all that has been written upon this subject, we are advanced but a very little way; those who have had skill to make proper observations, have wanted opportunity, and those who have had opportunity, have been deficient either in skill or attention.

Before we advert to the displeasing disposition of the eyes, termed *squinting*, it will be proper to consider that curious phenomenon of vision, by which we are enabled to see objects single with two eyes; for two pictures of the object are formed, one on each retina, each picture exhibits the object to us in a certain direction, yet we in general perceive only one object. Whenever we look attentively at any object, the axes of both eyes are directed towards it, and we are so accustomed to turn both eyes towards the same place, that if one eye be shut, it's motion will follow that of the other. This concurring motion has been one of the reasons

assigned, why an object seen with both eyes appears single; but this, like most other solutions of this phænomenon, is very unsatisfactory, for the eye sees not the concurrence of these imaginary axes: whatever be the cause, we are assured of the fact, that when both eyes look at the same object, the mind sees that object single.

Dr. Reid, who has considered this subject* with much attention, resolves the whole into a law of nature, laying it down as a general fact, or phænomenon of vision, that in perfect human eyes, the centers of the two retinae correspond and harmonize with one another, and that every other point in one retina, corresponds with that point which is similarly situated in the other. When the pictures fall, therefore, on corresponding points of the two retinae, one object only will be seen, though there should be really two; and the pictures falling upon the points of the retinae that do not correspond, will occasion two visible appearances, although there be but one object. Pictures upon corresponding points of each retina, raise in the mind a sensation of the same appearance, as if they had fallen upon the same point of one; while pictures falling upon points of the two retinae, which do not correspond, give the mind the idea of two distinct objects.

If we distort unnaturally our eyes from their parallel direction, or if, while we direct the axes of the two eyes to one point, and at the same time exert our attention, which is also unnatural, on another object, either much nearer, or much further, in these cases we see one object double, or two confounded in one.

The laws of vision, in the human constitution, are wisely adapted to the natural use of the eyes, but not to that which is unnatural; when we are obedient to the laws of order, as manifested in nature, we see objects properly, but have false appearances presented to us, when we use them in an unnatural manner. No part of the human constitution is more to be admired, than that whereby we acquire habits which are found to be useful, without any design or intention.

Squinting is attributed to a variety of causes; in many instances, it is undoubtedly owing to a prevailing principle of human action, habit induced by imitation: at other times to habit, brought on from the peculiar circumstance in which the eye happens to be placed.

* Reid's Inquiry into the Human Mind, p. 282.

A new born infant is incapable of fixing his eyes on any object, he moves one without moving the other,* or moving it in a contrary direction, rolling them about, being unable to discriminate one object from another; but as the body grows stronger, the eye becomes fortified and capable of obeying the action, and receives the impressions of the mind, which now directs the optical axes towards the same point, which direction becomes afterwards so natural, that in process of time it can scarce be altered even by the efforts of the will.

But while the powers of the body are weak, if the infant be so placed in it's bed, or cradle, as to view the light or any agreeable object, from one side only, it will probably learn to squint; for though at first he may discern the object with both eyes, yet as this requires some exertion, and that perhaps rather painful, he soon relaxes of his labour, and turns only that eye which is near the object, from which, if often practised, he forms the habit of moving his eyes differently; the same aptness to turn the eyes in contrary directions may be brought on, by often presenting to them, at the same instant, a variety of objects.

A cold in the head, a lowness of spirits, or a continued exertion or poring of the eyes, will often occasion those to squint, that are not accustomed to do it at other times. This is probably occasioned by a soreness or tenderness of the retina, which makes the impressions of light so offensive, that the eyes are forced into an unnatural direction; that by seeing obscurely, pain may be avoided: or it may be an affection of the muscles of the eye. This distemper may be cured, by using flat green glasses, or any other contrivance that will lessen the light. This soreness may also be a fixed distemper in one eye; the person will then turn it on one side, not that he may see better, but to avoid seeing with it at all.

This defect may be produced by a spasm in the muscles that move the eye, or by some of them being either too short or too long, too rigid or too lax. If, by any of these means, the natural equilibrium be destroyed, the eye will be turned too much one way; among these causes, some are beyond, and others within, the reach of medicine: of the various tonics that may be applied, electricity will probably be found the most powerful, and most efficacious.

* This is denied by Reid, on the authority of his own observation on his own children, and from the information of others.

An oblique position of the crystalline, or the cornea, will occasion squinting; in either of these cases, no assistance can be derived from art. The object to which the eye is directed is not distinctly seen, because its image does not fall upon those parts of the retina that are best suited to answer the purposes of vision.

One part of the retina is generally supposed to be more sensible than another, and that we turn our eyes, so that this part may receive the impressions of the light; but if this part be awry in one or both eyes, the person will necessarily squint.

Dr. Jurin, Mr. Buffon, and Dr. Reid have shewn, that the greatest number of those that squint have very indistinct vision with one eye. Indeed, M. Buffon asserts, that the true and general cause of this disease is an inequality in the limits of distinct vision in the two eyes; when one eye is more feeble than the other, we do not direct it towards the object, but make use of that which is stronger. Dr. Jurin observes, that those who squint, and see with both eyes, never at the same instant see the same object with both eyes; for when one eye is turned directly towards an object, the other is drawn so close to the nose, that to it the object is invisible. In some squinting eyes he observed the diverging eye to be drawn under the upper eyelid, while the other was directed to the object.

Dr. Reid recommends eleven subjects of inquiry to those who may meet with cases of this disorder, as necessary not only for giving us a true insight into this subject, but also for laying the foundation of a rational mode of cure; these I shall therefore subjoin.*

1. We ought to inquire whether the squinting person sees equally well with both eyes? and if there be a defect in one, the nature and degree of that defect should be investigated. The observer must not, in this case, rely upon the testimony of the patient; but must make such experiments as will be proper for drawing a just conclusion. In all the succeeding heads of inquiry, the patient is supposed to see so well at least with both eyes, as to be able to read with either, when the other is covered.

* Reid on the Human Mind.

2. When one eye is covered, we must see whether the other is turned directly towards the object. If the squinting eye turns aside from the object when the other is covered, it would prove that in that instance De la Hire's famous hypothesis was true. In all the cases, however, that have been tried by Mess. Jurin, Porterfield, and Reid, the contrary has taken place, and the axis of the squinting eye was turned directly towards the object, when the other was covered.

3. We ought to see whether the axes of the two eyes follow each other, so as to have always the same inclination, or form the same angle, when the person looks to the right or to the left, upward or downward, or strait forward; this will determine whether a squint be owing to any affection of the muscles. In the following heads of inquiry, the inclination of the axes of the eyes is supposed to be always the same.

4. Whether the patient sees an object single or double.

There is, probably, always a greater or less distortion of the eyes where there is double vision; yet it is certain that there is not always double vision where there is a squint; there are, perhaps, no instances where double vision has lasted any length of time. In the following inquiry we shall take it for granted, that the squinting person sees objects single.

5. Our next inquiry should be, whether the object is seen with both eyes at the same time, or only with that eye whose axis is directed towards it.

Most writers before Dr. Jurin, took it for granted, that those who squint see objects single with both eyes at the same time: it is an opinion unsupported by facts, and the truth of it denied by Jurin. It is very easy, in any particular instance, to decide the question. While the person that squints looks steadily at any object, let the observer carefully remark the direction of both eyes, and observe their motions; and let an opaque body be placed between the object and each eye successively. If the patient, notwithstanding this interposition, and without changing the direction of his eyes, continues to see the object all the time, we may fairly conclude that he saw it with both eyes at once. But if the interposition of the opaque body between one eye and the object makes it disappear, then we may be as sure that it is seen by that eye only.

In the next two articles we suppose the first to happen, according to the generally received hypothesis.

6. On this supposition, it ought to be inquired whether the patient sees an object double in those cases, where it appears double also to those who do not squint.

For this purpose, let him place a candle at the distance of ten feet, and holding his finger at arm's length between him and the candle, let him observe when he looks at the candle, whether he sees his finger with both eyes, and whether he sees it single or double; and when he looks at his finger, let him observe whether he sees the candle with both eyes, and whether it appears single or double.

If the patient is found to see objects single with two eyes, not only in the cases wherein they appear single, but also where they appear double to other men, we may conclude, that his single vision does not arise from correspondent points in the retinae of his eyes, and that the laws of vision are different in him, from what they are in the rest of mankind.

7. If, on the other hand, he sees objects double in those cases wherein they appear double to others, we must conclude that he has corresponding points in the retinae of his eyes, but that they are situated unnaturally. If the common hypothesis be true, that one who squints sees an object with both eyes at the same time, and yet sees it single, the squint will probably be of the kind described in this article; and we may conclude, that if a person, affected with such a squint as we have here supposed, could be brought to the habit of looking strait, it would be highly prejudicial to the sight: for he would then see every thing double which he saw with both eyes at the same time, and objects distant from each other would be confounded together; his eyes are made for squinting, and the cure would be worse than the disease, as it is far better to squint, than to purchase the cure, by the loss of perfect and distinct vision.

8. We may after these trials return to the hypothesis of Dr. Jurin, and suppose, that the patient when he saw objects single, notwithstanding his squint, was found, upon trial, to have seen them only with one eye.

The patient must now be advised by repeated efforts to lessen his squint, and to bring the axes of his eyes nearer to a parallel direction; we have a power of making small variations in the inclination of the optic axes, and this power may be greatly increased by exercise, by perseverance, and patience. If the practice is begun while the patient is young, he will probably soon learn to direct both his eyes to one object. When this power is acquired, it will be easy to determine, whether the center of the retinae, and points similarly situated with respect to these centers, correspond as in other men.

9. Let us now suppose this to be the case, and that he sees an object single with both eyes, when the axes of both are directed to it.

It will then be his business to acquire the habit of looking strait, as he will thereby not only remove a disagreeable deformity, but considerably improve his sight.

10. As the case mentioned in the ninth article is not merely hypothetical, but founded on absolute fact, it will be necessary further to inquire, how it happens that such a person sees an object at which he is looking only with one eye, when both are open?

To elucidate this question, we must again go to experiment, and observe, first, Whether our patient, when he looks at an object, does not draw the diverging eye so close to the nose, that it can have no distinct images? or secondly, Whether the pupil of the diverging eye is not covered wholly, or in part, by the upper eyelid? thirdly, Whether the diverging eye is not so directed, that the picture of the object falls upon that part of the retina, where the optic nerve enters, and where there is no vision? This is probably the case in a squint, where the axes of the eyes converge so, as to meet about six inches before the nose.

11. In the last place we should inquire, whether the person has any distinct vision at all with the diverging eye, at the time he is looking at an object with the other; for though the person may be able to read with the diverging eye, when the other is covered, yet when both are open it may have no distinct vision.

The foregoing inquiries are much easier in theory than practice, and for insuring success, some qualifications of mind are necessary in the patient, which are not always to be met with; but a due attention to them, where there is opportunity, will soon furnish us with more important facts than we are at present acquainted with: by these facts vain theory will be exploded, and our knowledge of the laws of nature, with regard to the noblest of our senses, enlarged.

Of the Method of Cure.

We suppose the preceding inquiries to have been made, previous to any attempts towards a cure; if, in consequence of these, we find that the cure will not be prejudicial to the patient's sight, we may proceed to try any of the following methods; the first is that proposed by Dr. Jurin. "When the patient is of an age capable of attending to the following directions, place him directly before you, and let him close the undistorted eye, and look at you with the other; when you find the axis of this eye fixed directly upon you, bid him endeavour to keep it in that situation, and open his other eye; you will now perceive the distorted eye turn away from you towards the nose, and the axis of the other eye will be pointed towards you. By patience and repeated trials, he will be able to keep his distorted eye fixed upon you, at least for a little time after the other is opened, and when you have brought him to keep the axes of both eyes fixed upon you, while you stand directly before him, it will be time to change his posture, and to place him a little on one side of you, and then on the other, continuing the same practice; when he can in all situations perfectly and readily turn the axes of both eyes towards you, the cure is effected; this will be forwarded by his frequently practising before a mirror, and by having a friend always at hand, to observe and admonish him when he squints.

Messrs. Buffon, Reid, and Darwin, concur in recommending the patient to cover the good eye, as the most effectual and natural method of cure, as by frequent use, the sight of the weak eye is strengthened, and acquires a habit of turning to the objects which the patient wishes to see; and the better eye by losing something in this respect facilitates greatly the cure;

the inequalities in the eyes should, however, be first well ascertained because this method will not succeed if there is too great a difference. M. Buffon says, that if the eye that squints be turned towards the temples, there is seldom any great inequality between them, and that in this case, the disorder arising only from a vicious habit, he has known the cure to be completed, by covering the good eye for a fortnight only: it is necessary to cover the good eye for some time, in order to exercise and strengthen the bad eye, that a proper judgment may be formed of the possibility of the cure.

In the 68th vol. of the Philosophical Transactions, Dr. Darwin has given an account, of which the following is an extract, of a very curious and confirmed case of squinting, and of the method he used for curing it.

The patient was a boy five years old, who viewed every object that was presented to him with but one eye at a time.

If the object was presented on the right side, he viewed it with his left eye; if it was presented on the left, he viewed it with the right eye.

He turned the pupil of that eye which was on the same side with the object, in such a direction, that the image of the object might fall upon that part of the bottom of the eye, where the optic nerve enters it.

When an object was held directly before him, he turned his head a little on one side, and observed it but with one eye, namely, that most distant from the object, and when he became tired of observing it with that eye, he turned his head the contrary way, and observed it with equal facility with the other eye, but never turned the axes of both eyes towards it at the same time.

He saw letters which were written on bits of paper, so as to name them with equal ease, and at equal distances, with one eye as the other.

There was no perceptible difference in the diameter of the pupils, or their degree of contractability, after having covered his eyes from the light.

The foregoing observations were carefully made, by writing single letters on shreds of paper, and laying wagers with the child, that he could not read them when they were presented at certain distances, and in certain directions.

As from these circumstances it appeared that there was no defect in either eye, and that the disease was simply a depraved habit, there was great room for hopes of success in the cure.

For this purpose a proper gnomon was made and fixed to a cap, and when this artificial nose was placed over the real one, so as to project between his eyes, the child rather than turn his head to look at oblique objects, began to view them with that eye which was next to them; the father of the child dying, the cure was neglected for six years, and though the habit was so confirmed as to leave little room for a cure, the same physician being called, he again attempted to remove the deformity by a similar contrivance.

A gnomon of thin brass was made to stand over his nose, with a half circle of the same metal to go round his temples; they were covered with black silk, and fixed by means of a buckle behind his head, and a cross piece over the crown of the head; this gnomon was worn without inconvenience, and projected before the nose about two inches and a half. By the use of this he soon found it less inconvenient, to view all oblique objects with the eye next them, instead of the eye opposite to them.

After this habit was weakened by a week's use of the gnomon, two bits of wood, about the size of a goose quill, were blacked, all but a quarter of an inch at their summit. These were frequently presented to him to look at, one being held on one side of the extremity of his black gnomon, and the other on the other side of it. As he viewed these, they were gradually brought forward beyond the gnomon, and then one was concealed behind the other; by these means, in another week he could bend both his eyes on the same object, for half a minute together, and by continuing the use of the same apparatus, he was in a fair way of recovery, when the paper was written for the transaction.

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